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EVALUATION OF SEATING AND RESTRAINT SYSTEMS
AND ANTHROPOMORPHIC DUMMIES
CONDUCTED DURING FISCAL YEAR 1976

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16. Abstract The results of test programs conducted by the Protection and Survival Laboratory to investigate the performance of prototype or operational seating and restraint systems relative to their ability to provide protection against crash injury and to investigate the performance of anthropomorphic dummies in the dynamic environment are reported. The data in this report were previously presented as the final quarterly progress report for Task AM-B-77-PRS-47 and are subject to additional evaluation or change on review, conduct of additional testing, or receipt of additional facts.		
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EVALUATION OF SEATING AND RESTRAINT SYSTEMS AND ANTHROPOMORPHIC DUMMIES CONDUCTED DURING FISCAL YEAR 1977

INTRODUCTION

This report summarizes the results of test programs conducted by the Protection and Survival Laboratory to investigate the performance of prototype or operational seating and restraint systems relative to their ability to provide protection against crash injury and to investigate the performance of anthropomorphic dummies in the dynamic environment.

METHOD

The system evaluations were conducted on the Civil Aeromedical Institute (CAMI) test track. This is an impact test device capable of producing a controlled deceleration pulse that can be programmed to produce decelerations between 2 and 50 g, as required for a specific test. The device consists of a test sled that carries the test item along two 150-ft-long horizontal rails, an accelerating device that brings the sled up to the desired impact velocity, and a sled braking device that produces the desired impact pulse.

The sled is a flat-topped steel truss on which the test item is mounted. By the use of adapters, a variety of test items can be attached to the sled so that the impact vector, which lies in a horizontal plane, can act on the test item in the desired direction. The sled is equipped with low-friction rollers that guide it along the rails of the track with minimal energy loss.

Velocity is imparted to the sled by an accelerating device that includes a 6,400-lb weight, a cable system with a 4-to-1 mechanical advantage attached between the sled and the weight, and a winch cart that can be positioned and locked at any point along the track. The winch cart retracts the sled and locks it into the "ready" position just prior to the test and, simultaneously, it lifts the weight. As the weight is lifted, potential energy is stored in the system and is subsequently used to accelerate the sled and test item to the desired impact velocity. A maximum of 110,000 ft-lb of energy can be stored that can accelerate the sled and payload to velocities of up to 50 mi/h, depending on the payload weight. To accomplish the test, the sled is released from its locked position, is accelerated along the track by the falling weight, is allowed to coast without acceleration for a predetermined distance after the weight is stopped, and then contacts the braking device which produces the desired impact pulse.

The braking device is a "metal bender" form of energy absorber. This device uses two layers of 1/4-in-diameter wires that are plastically deformed as they are pulled over rollers by the sled and thus absorb energy to provide the required braking force. The wires are cut to length with sufficient allowance to provide a safety factor above displacement required by the sled during the impact. The wire size and the diameter of the rollers over which it passes were selected to generate a nominally required force of 2,500 lb to pull the wire through the rollers. The braking device holds two layers of 10 wires and is thus capable of generating a braking force of 50,000 lb. The

deceleration-time history of the sled can be precisely controlled by selecting the number of wires placed in the braking device and adjusting the position at which they are contacted by the sled. The total deceleration distance is not limited by this braking device.

Component evaluations were conducted on specially built equipment that met the provisions of the specifications describing those tests.

ELECTRONICS INSTRUMENTATION

The electronic instrumentation system used by the Protection and Survival Laboratory for dynamic testing was designed for maximum versatility and reliability. Special provisions have been made for using strain gage bridge-type transducers. This type of transducer is available in many models and has proved to be reliable for measuring strain, acceleration, pressure, forces, and low frequency vibrations.

Signals are transmitted from transducers on the sled or test item to signal conditioners through a loose, flexible cable that is attached at one end to the sled. The signal conditioners (Endevco model 4470/4476.2) provide excitation to the transducers (3 to 10 V dc), amplify the signal, provide low-pass filtering if required, and provide resistance shunt calibration for each transducer through the entire data-recording system.

Outputs from the signal conditioners modulate subcarrier oscillators of a constant-bandwidth high frequency multiplexer system. The composite output from the multiplexer system is recorded on wideband analog tape that serves as primary data storage. The magnetic tape data are then reproduced through appropriate discriminators for recording on an oscillographic recorder (for quick-look analysis) or digitized and recorded on high-density digital tape for automatic data processing. Final data are processed in accordance with the requirements of Society of Automotive Engineers (SAE) Recommended Practice J211b, Instrumentation for Impact Tests, unless a specialized requirement exists.

PHOTOGRAPHIC INSTRUMENTATION

All dynamic tests are photographically recorded for technical documentation and for data collection. Instrumentation-quality 16-mm cameras of various types are operated with film speeds of 500 pictures/s (pps) or 1,000 pps to provide the necessary coverage with the required fields of view. Color film is used in all cameras and processed at CAMI for maximum picture quality. Synchronization of all cameras with the electronic instrumentation system and timing of all film is provided; both serial-coded pulses (IRIG-A or IRIG-B*) and numerical display are available on the film edge. Cameras and lighting are controlled by a 42-channel programming system that enables obtaining optimum frame rates during the impact event and prevents damage to the test specimen by the high-intensity lighting necessary for proper exposure. Film data are extracted and analyzed by using a Hewlett-Packard 9820 data system to digitize, store, analyze, and plot data as required.

*Inter-Range Instrumentation Group

OGLE/MIRA DUMMY EVALUATION PROGRAM

The Protection and Survival Laboratory is participating in a program with the National Highway Traffic Safety Administration (NHTSA) designed to evaluate the performance of anthropomorphic test dummies under specific test conditions. The goal of the program is to compare the data obtained from two separate test facilities when exposing two dummies of the same manufacturer and model number to a controlled test environment. In this manner, variability in dummy performance attributable to both dummy design and methods of use can be isolated. Component tests on the Ogle/Mira anthropomorphic dummies (OPAT Test Device, serial numbers 113 and 114) have been previously reported.¹ Sled test data are included in this report. The sled tests were of two types, the first type using a standard lapbelt and single diagonal belt upper torso restraint (Figure 1), and the second type using a preinflated air bag and rigid plastic foam knee bolster restraint (Figure 2). Each type of sled test was repeated 10 times for each dummy under operationally identical conditions to obtain an indication of the mean value and standard deviation of the results as shown in Figures 3 through 6.



Figure 1. Test configuration for lapbelt and single diagonal torso belt restraint system (Type II) sled test.

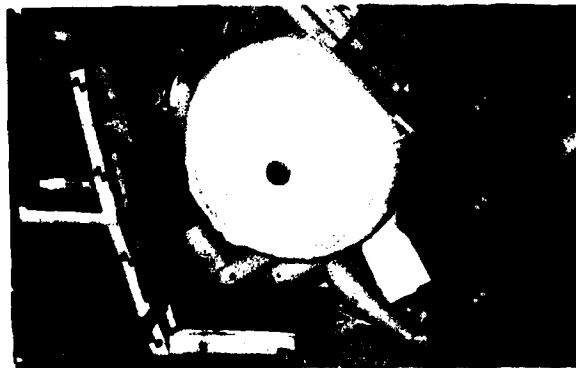


Figure 2. Test configuration for preinflated air bag and rigid foam knee bolster restraint system sled tests.

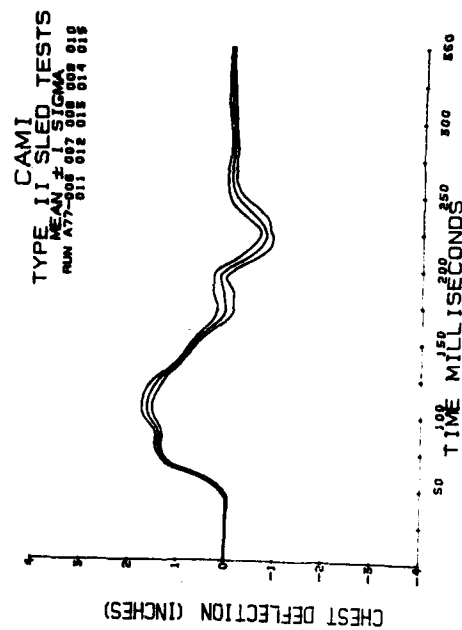
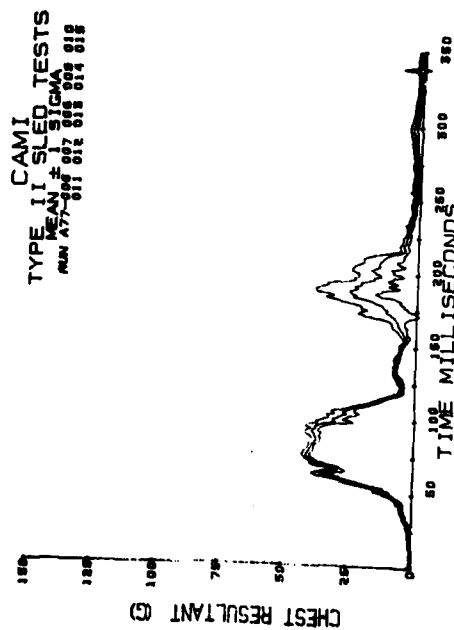
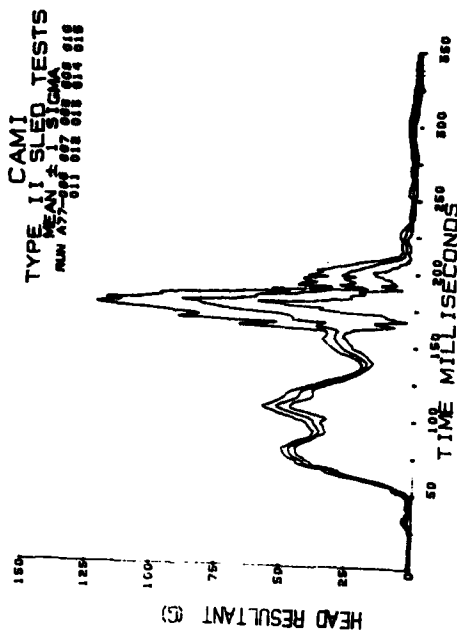
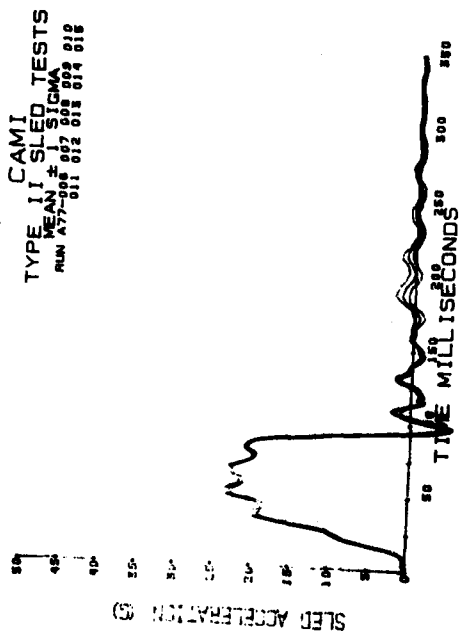


Figure 3. Lapbelt and diagonal belt upper torso restraint sled test data, dummy serial number 113.

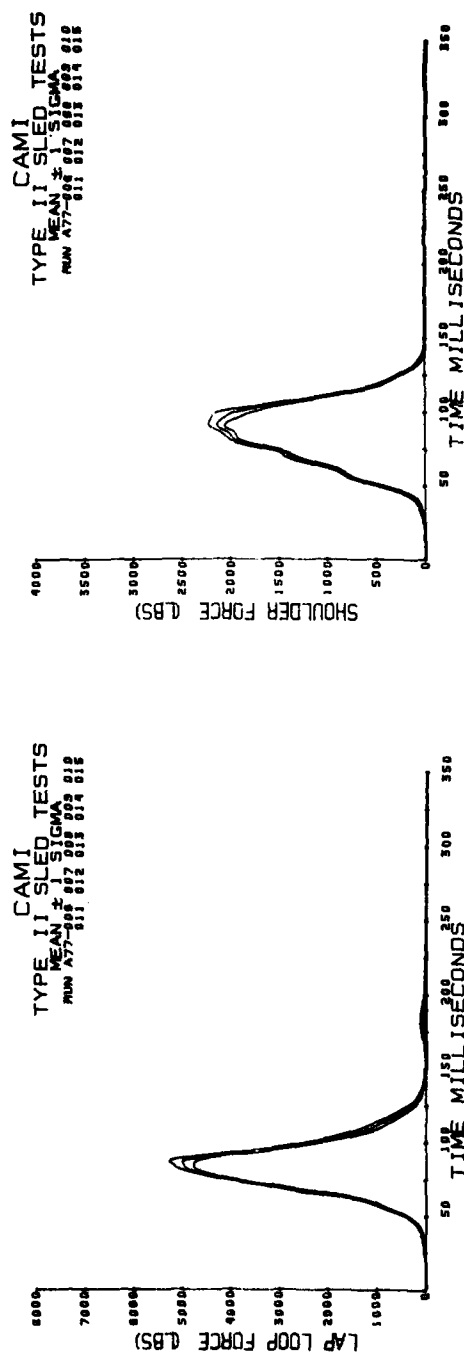
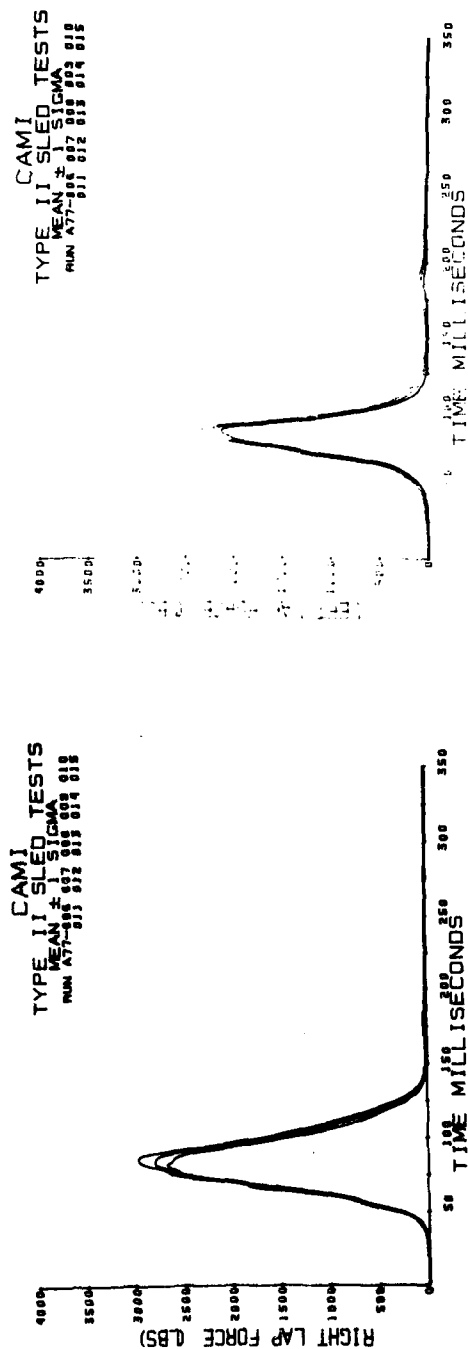


Figure 3. (continued).

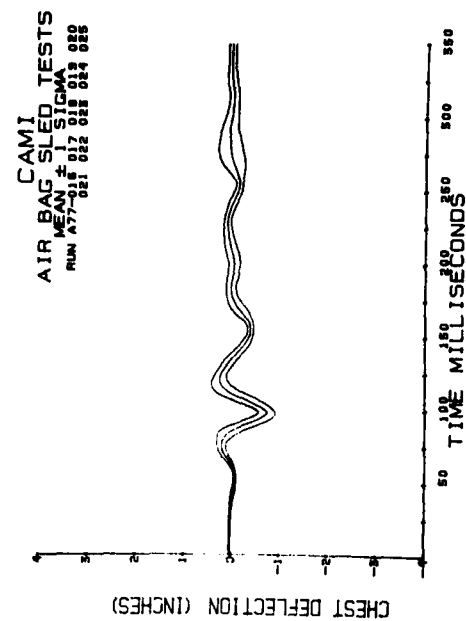
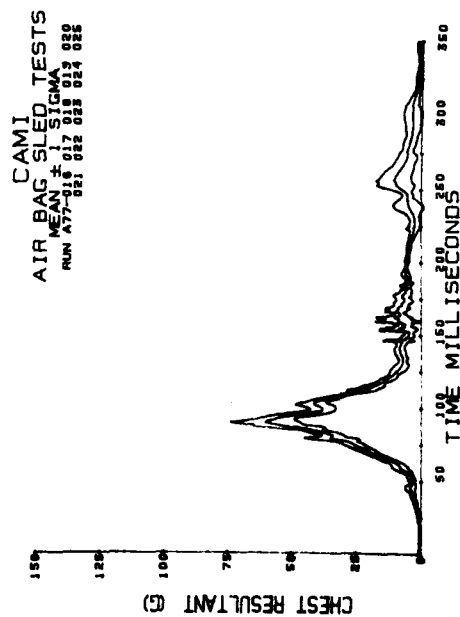
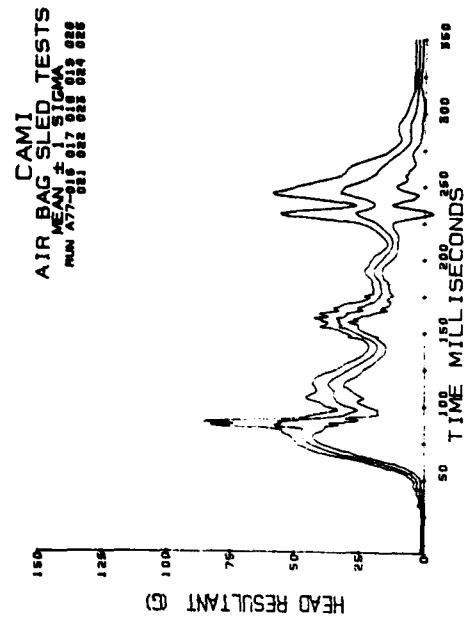
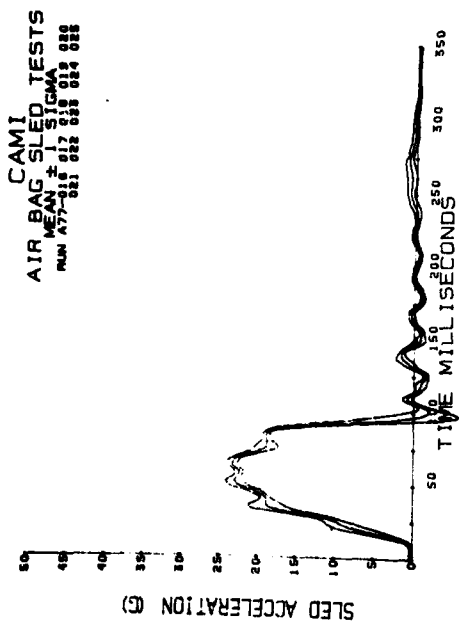


Figure 4. Air bag sled test data,
dummy serial number 113.

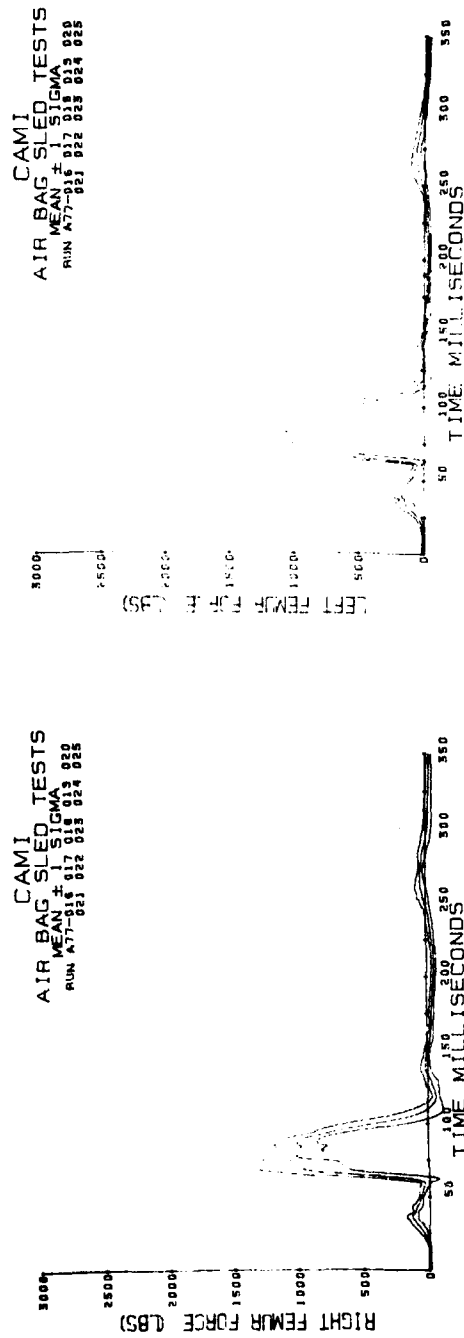


Figure 4. (continued).

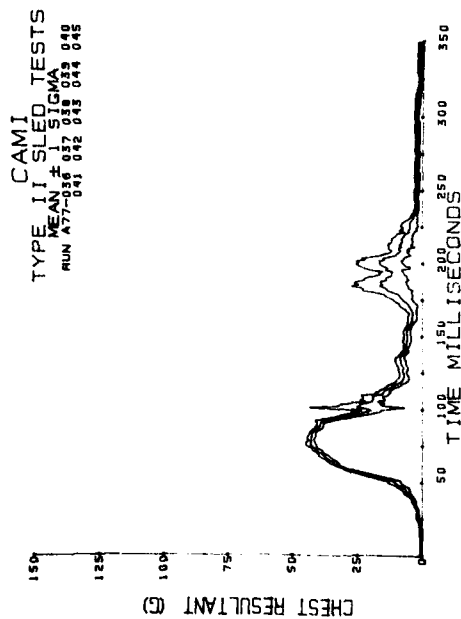
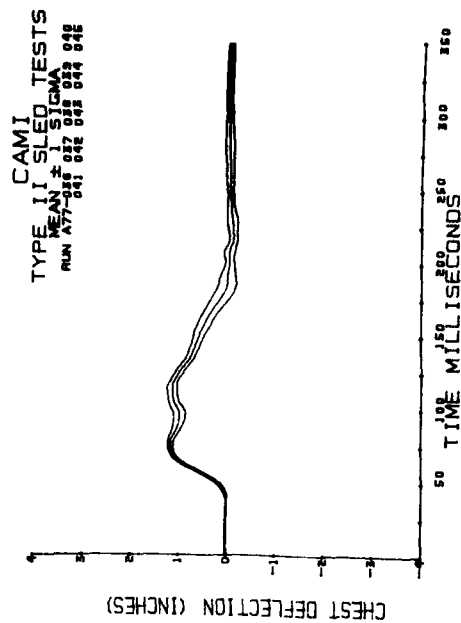
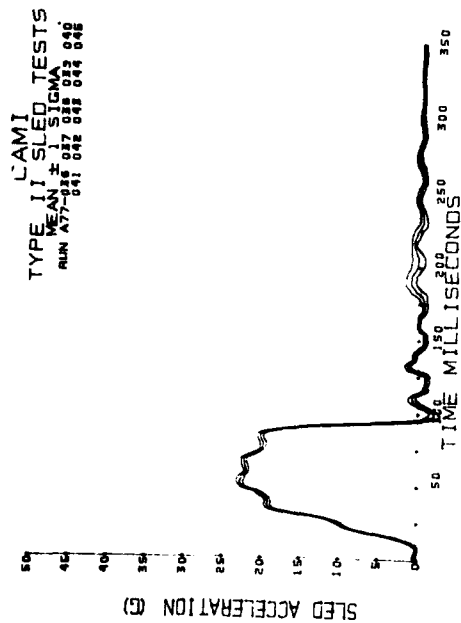
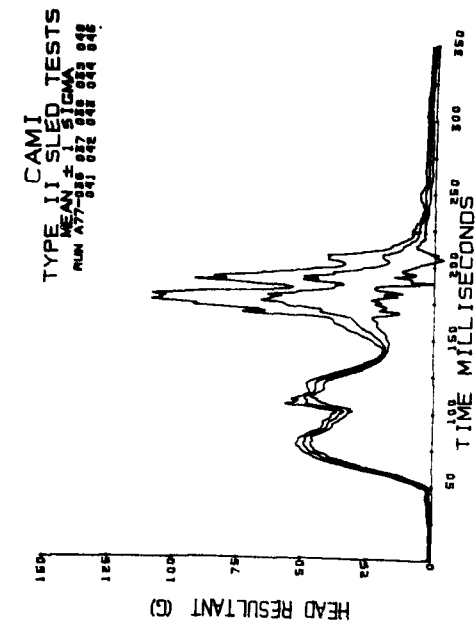


Figure 5. Lapbelt and diagonal belt upper torso restraint sled test data, dummy serial number 114.

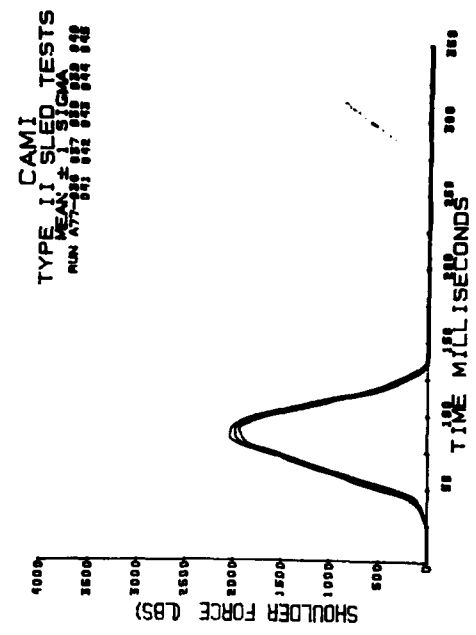
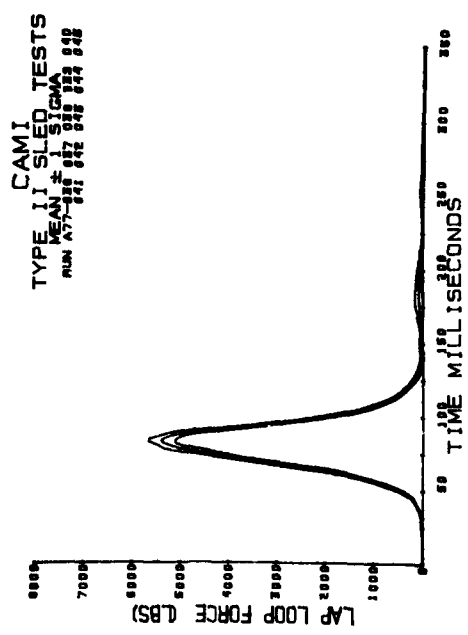
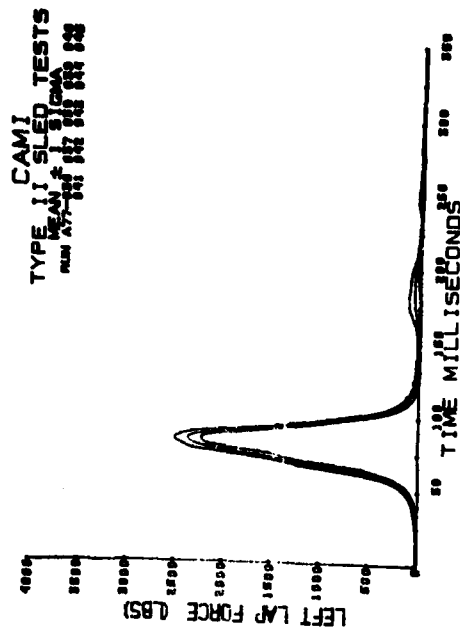
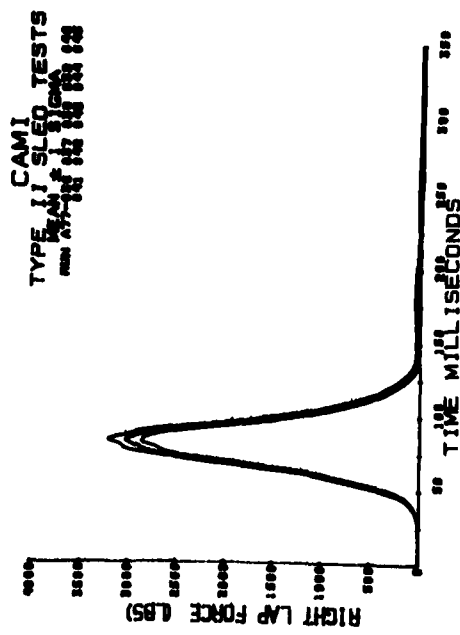


Figure 5. (continued).

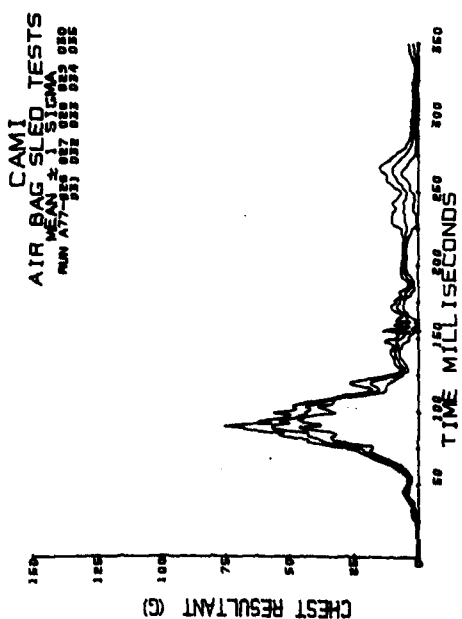
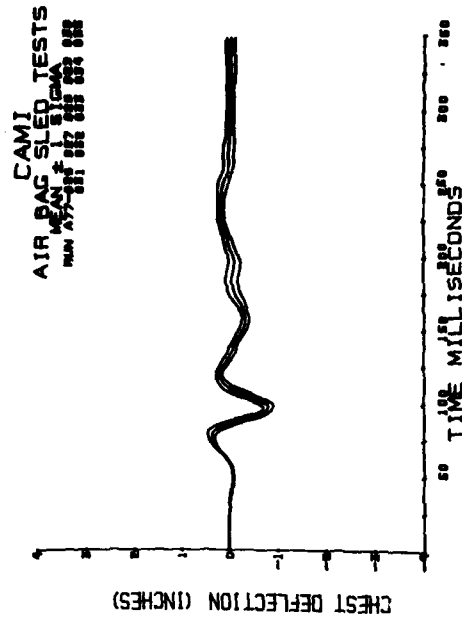
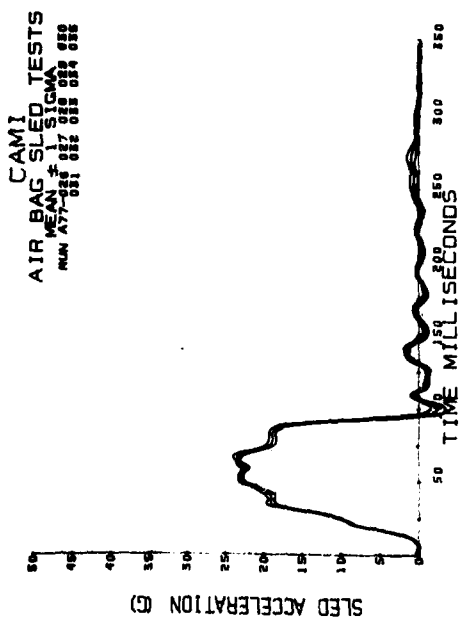
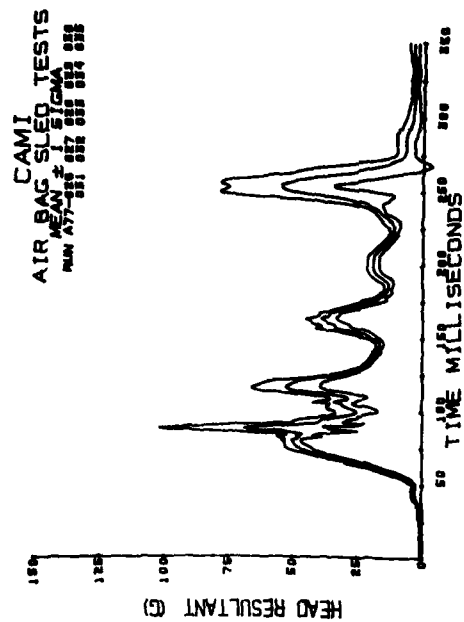


Figure 6. Air bag sled test data,
dummy serial number 114.

ITOH SEIKI DUMMY EVALUATION PROGRAM

Two Itoh Seiki Company, Ltd. (Tokyo, Japan) model 3DGM-AM50-73A anthropomorphic dummies were subjected to dynamic tests to provide data for evaluation of the repeatability of their performance and for comparison with other dummies tested under similar circumstances. These dummies were developed by Itoh Seiki in accordance with U.S. federal and SAE standards.^{2,3,4,5} Among the unique features of these dummies were pneumatically loaded ball joints for leg/pelvis connections and hydraulic cylinders for thorax damping. The sled tests were of two types, the first using a standard lapbelt and single diagonal belt upper torso restraint (Figure 7), and the second type using a preinflated air bag and plastic foam knee bolster restraint (Figure 8). These tests were repeated to obtain an indication of the mean value and standard deviation of the results, as shown in Figures 9 through 12. Submarining was noted on tests using the belt-type restraint system.



Figure 7. Test configuration for lapbelt and single diagonal torso belt restraint system (Type II) sled tests.



Figure 8. Test configuration for preinflated air bag restraint system sled tests.

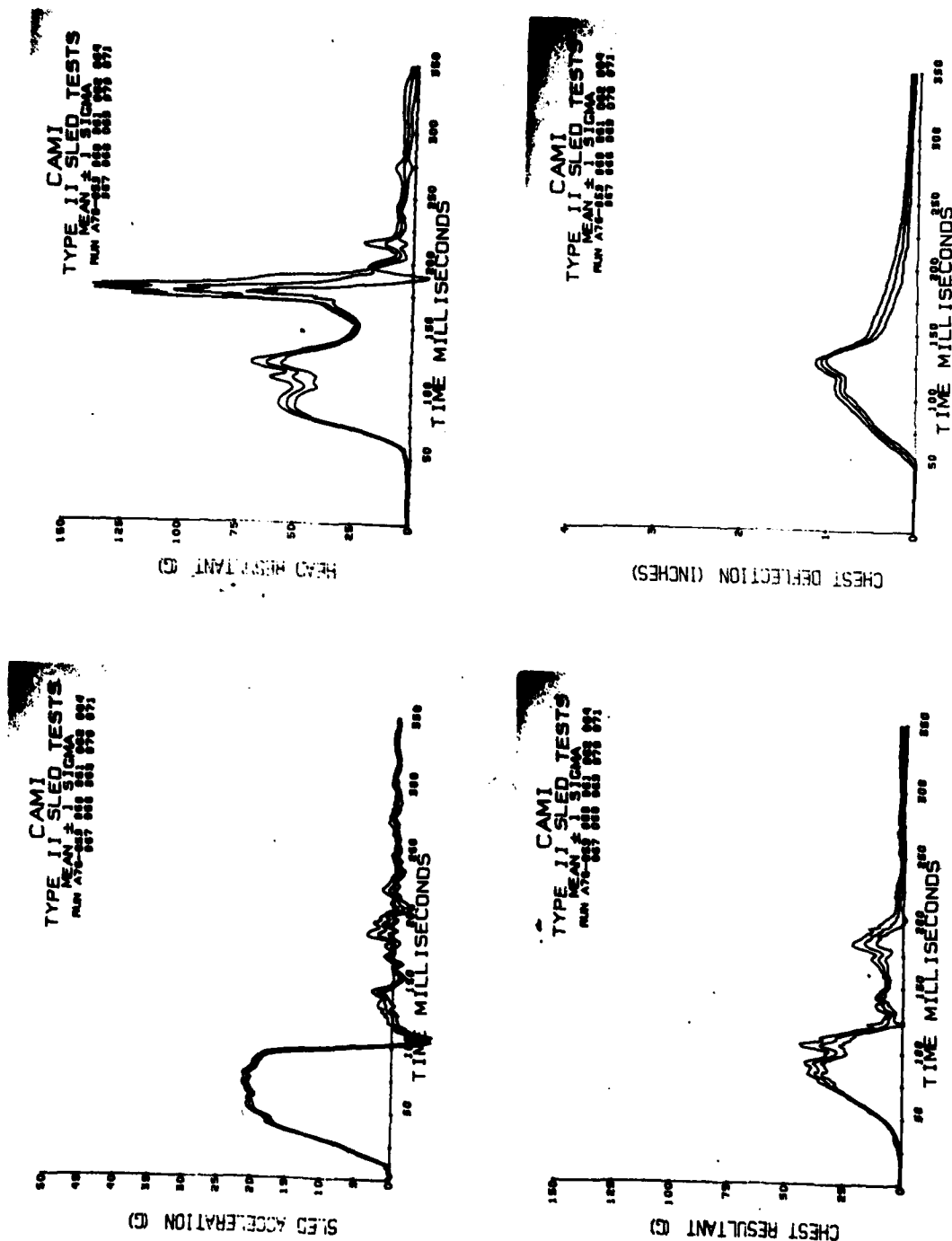


Figure 9. Lapbelt and diagonal belt upper torso restraint sled test data, dummy serial number 1.

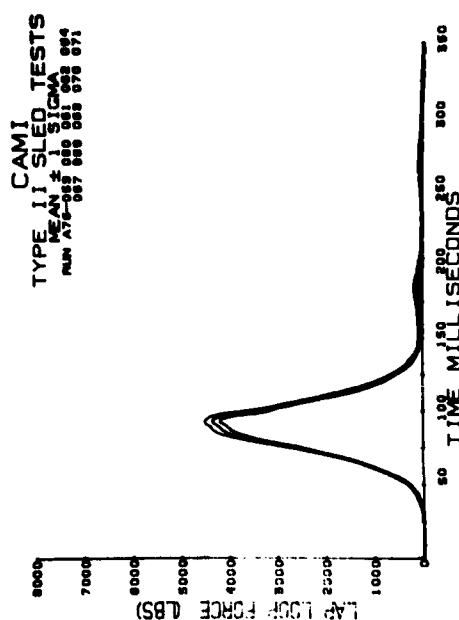
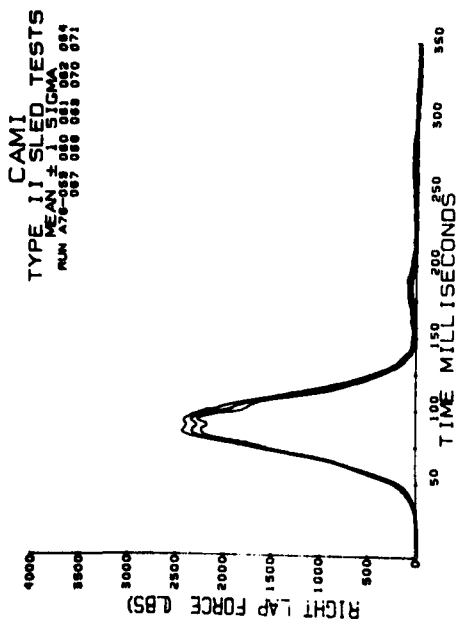
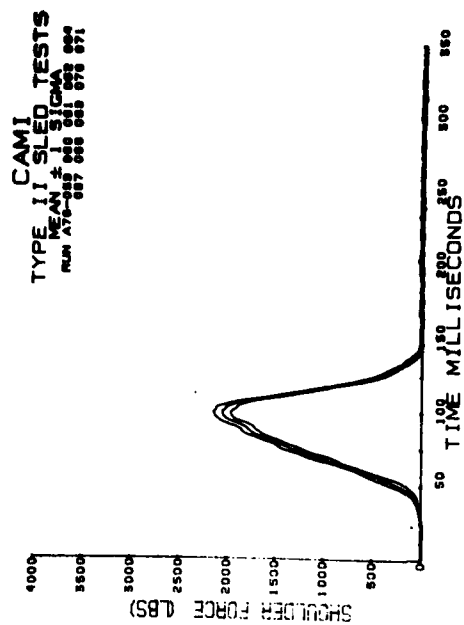
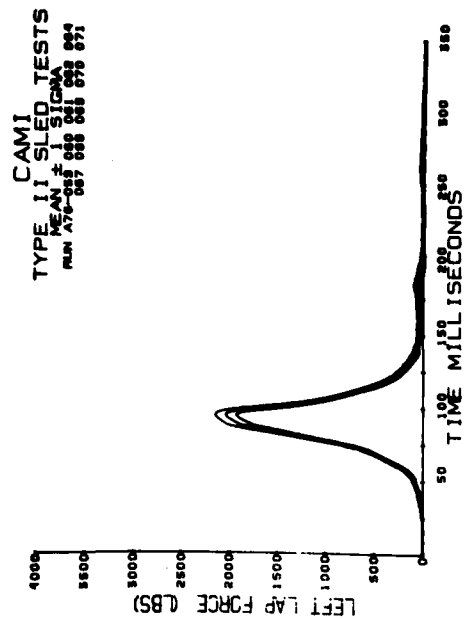


Figure 9. (continued).

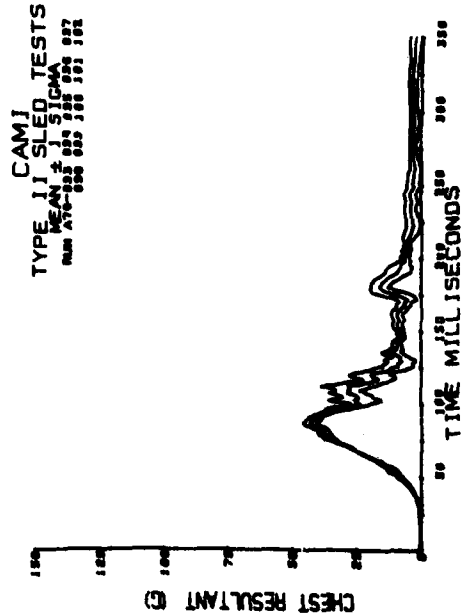
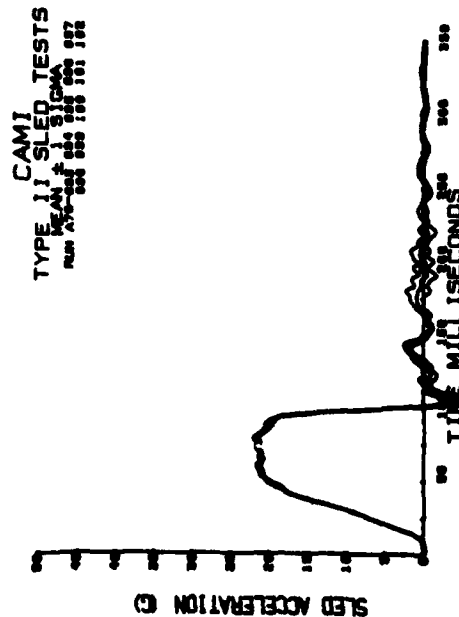
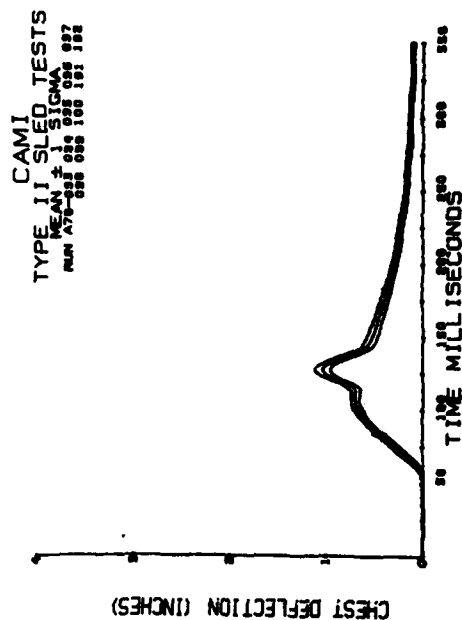
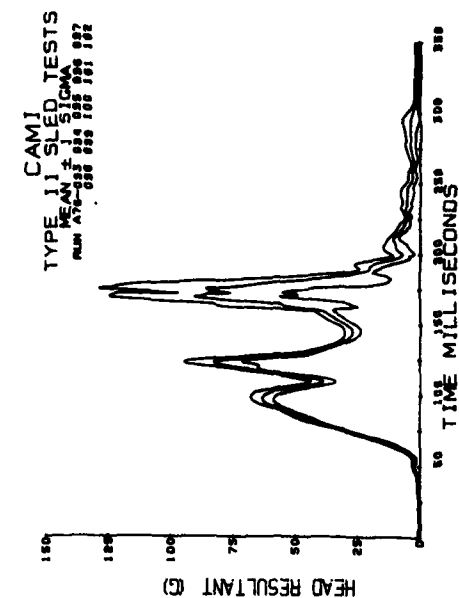


Figure 10. Lapbelt and diagonal belt upper torso restraint sled test data, dummy serial number 2.

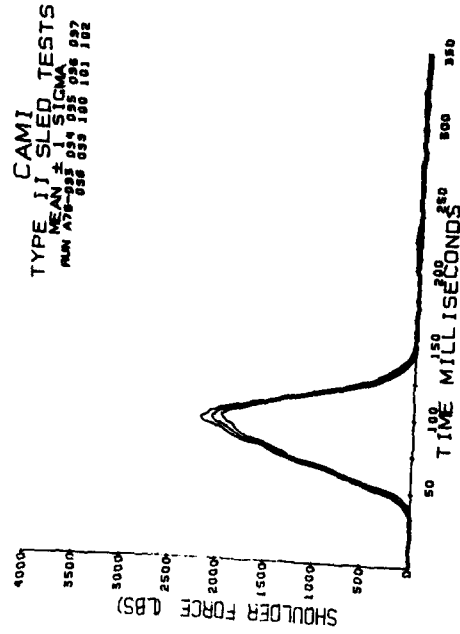
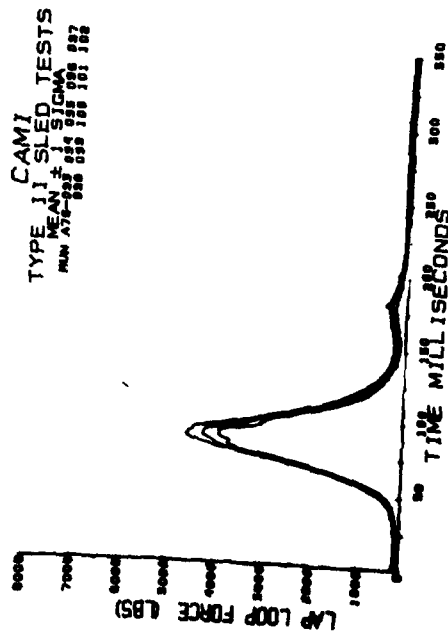
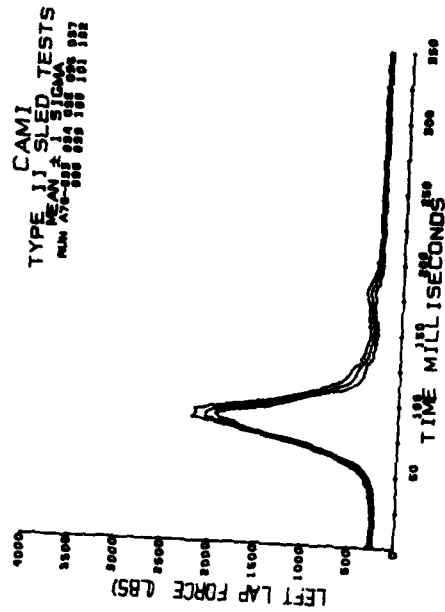
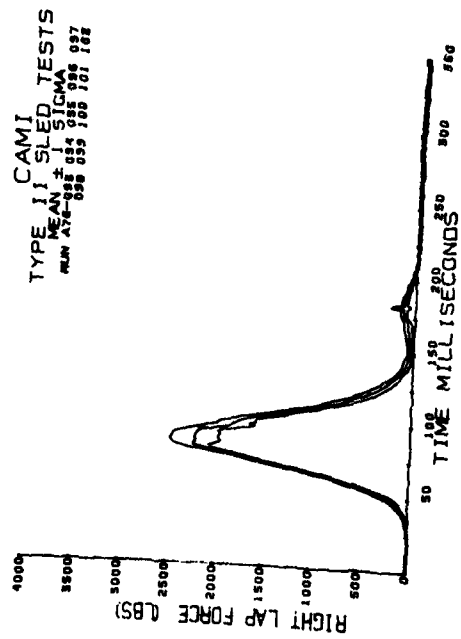


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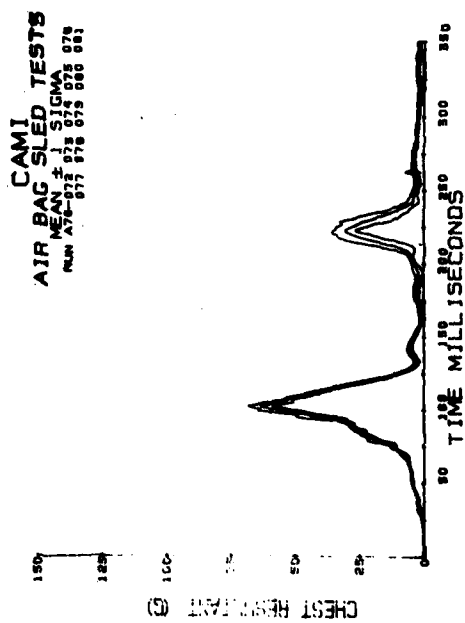
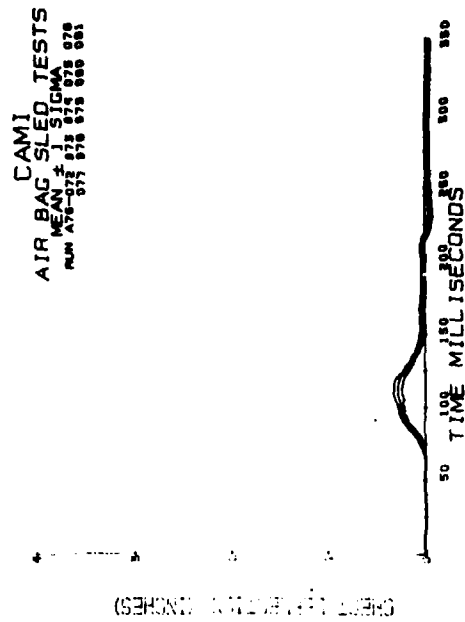
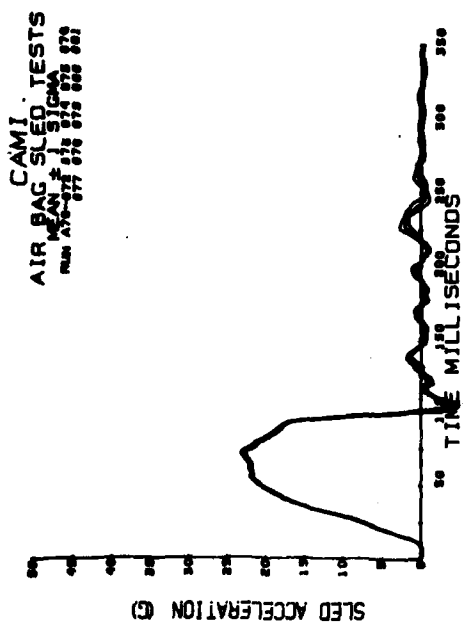
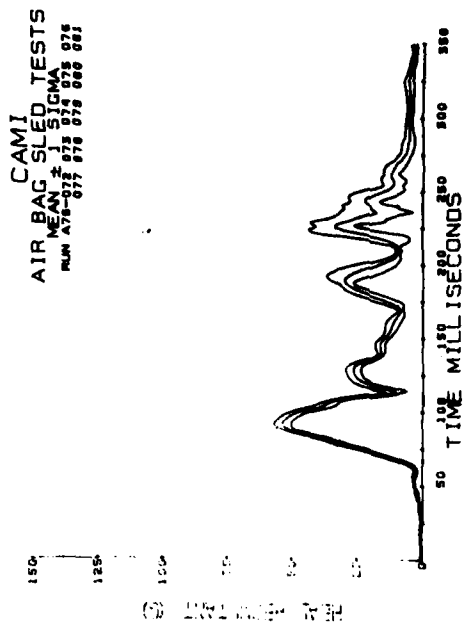


Figure 11. Air bag sled test data, dummy serial number 1.

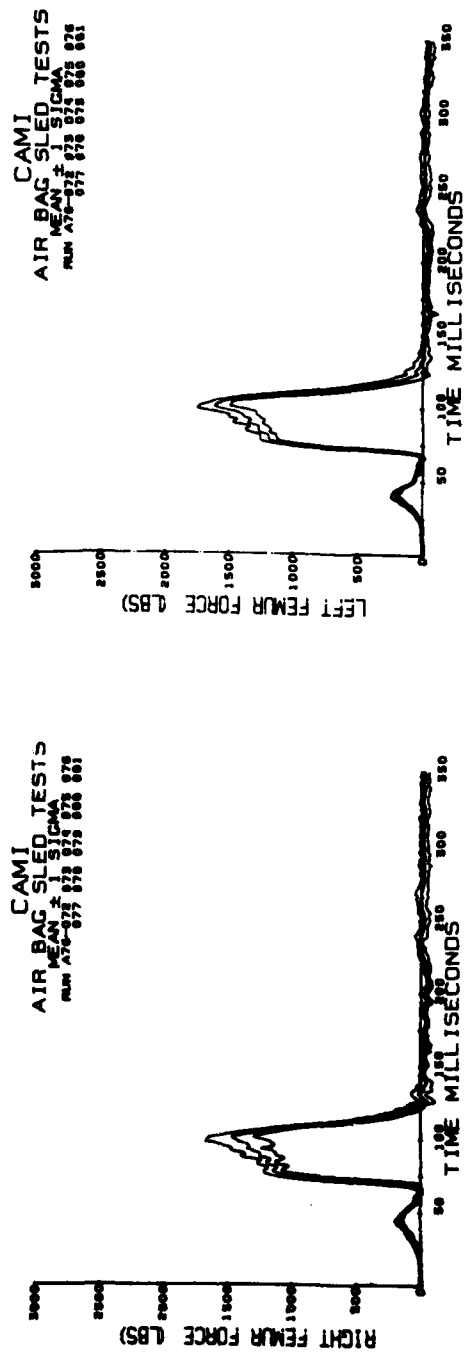


Figure 11. (continued).

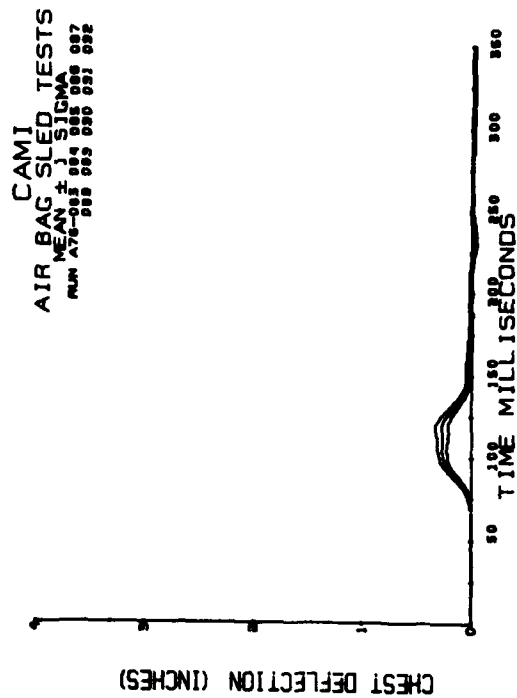
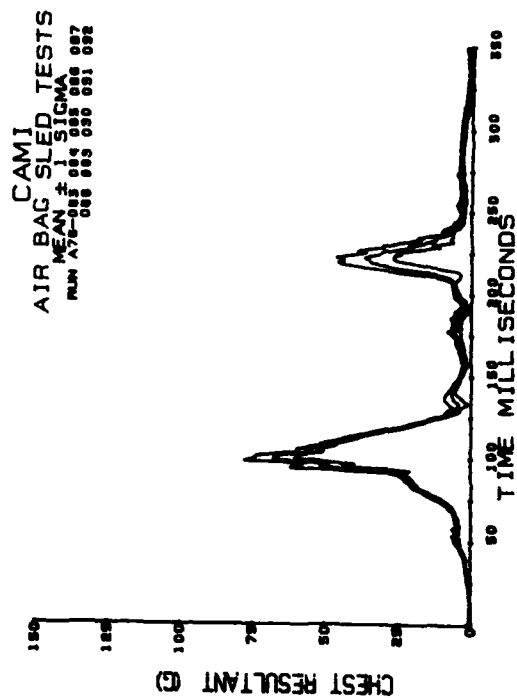
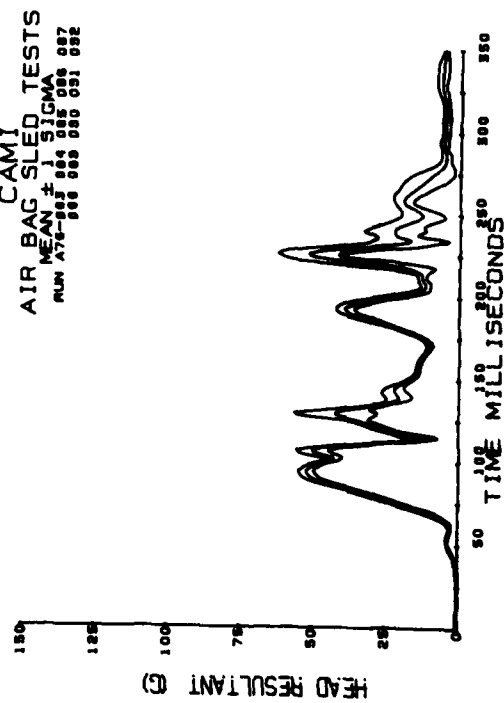
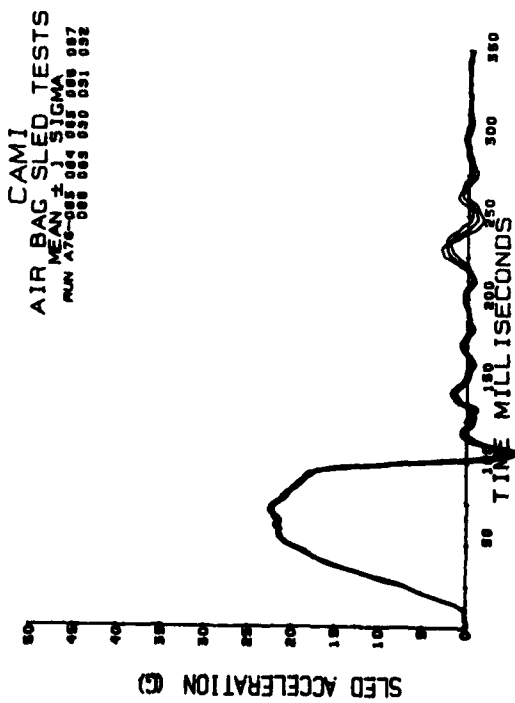


Figure 12. Air bag sled test data, dummy serial number 2.

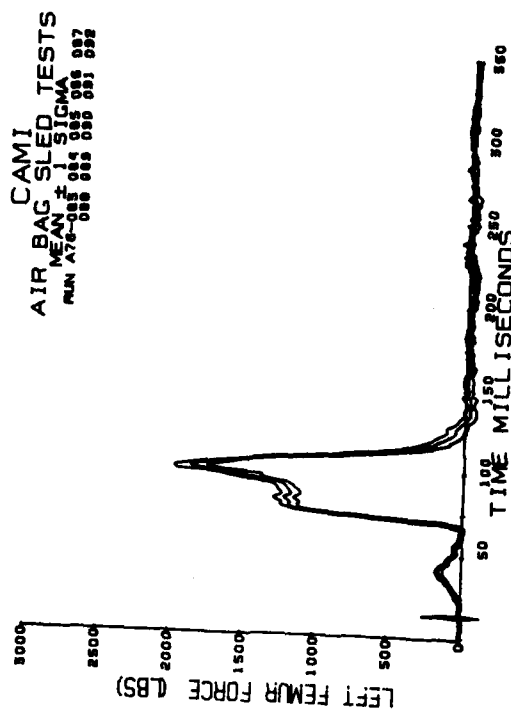
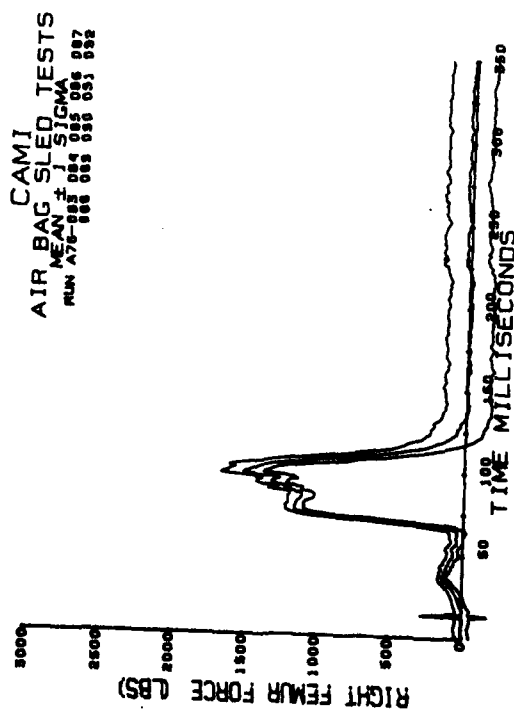


Figure 12. (continued).

Component tests were conducted in accordance with the NHTSA "Purchase Description of the NHTSA 50th Percentile Anthropomorphic Test Dummy."³ The results of the head drop tests are shown in Table 1, the static load test results of the torso are shown in Figure 13, and the dynamic load test results of the thorax are shown in Figure 14. Accelerations measured on the 35-in drop height tests exceeded the range of the data system.

TABLE 1. Head Drop Test Data

		<u>10-in Drop Height</u>	
		<u>S/N 1</u>	<u>S/N 2</u>
Deceleration, g	AVE	316.0	317.3
	S _x	11.9	9.4
GSI	AVE	937.6	987.3
	S _x	58.8	47.12

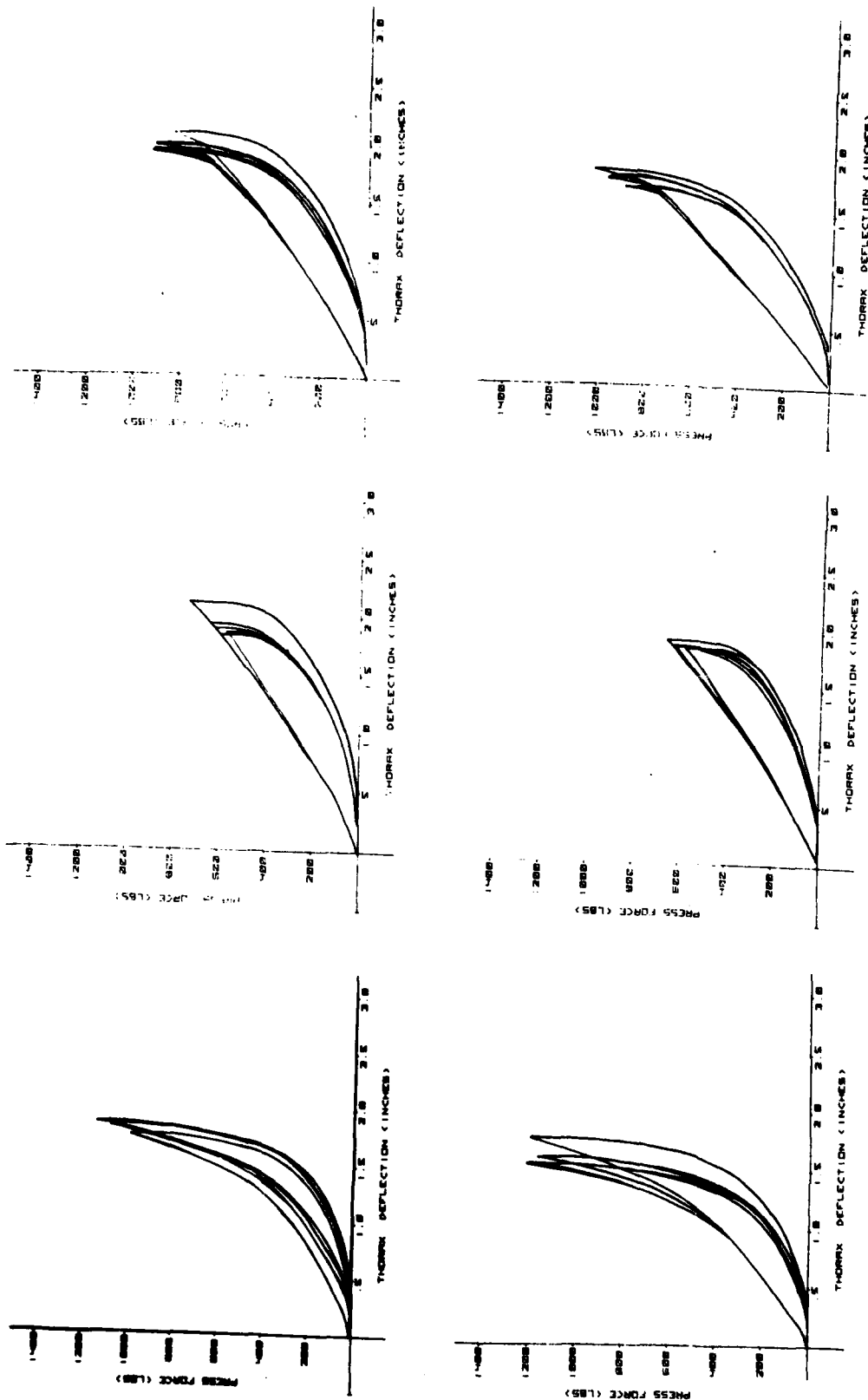
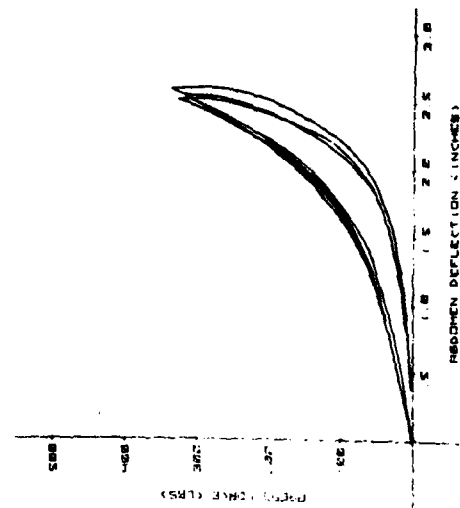
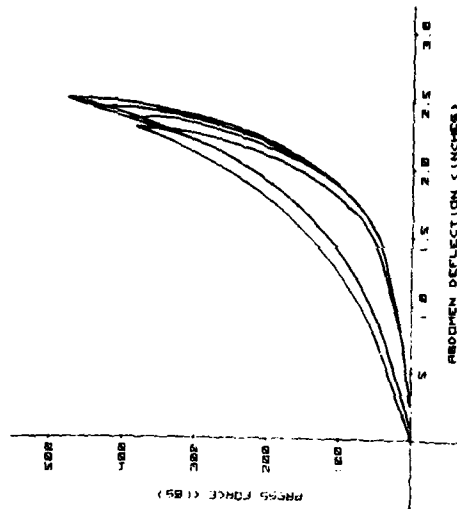


Figure 13. Static test data obtained on the torso, dummy serial number 1 (above) and dummy serial number 2 (below). Location of load application is shown below the figures.



Abdomen

Figure 13. (continued).

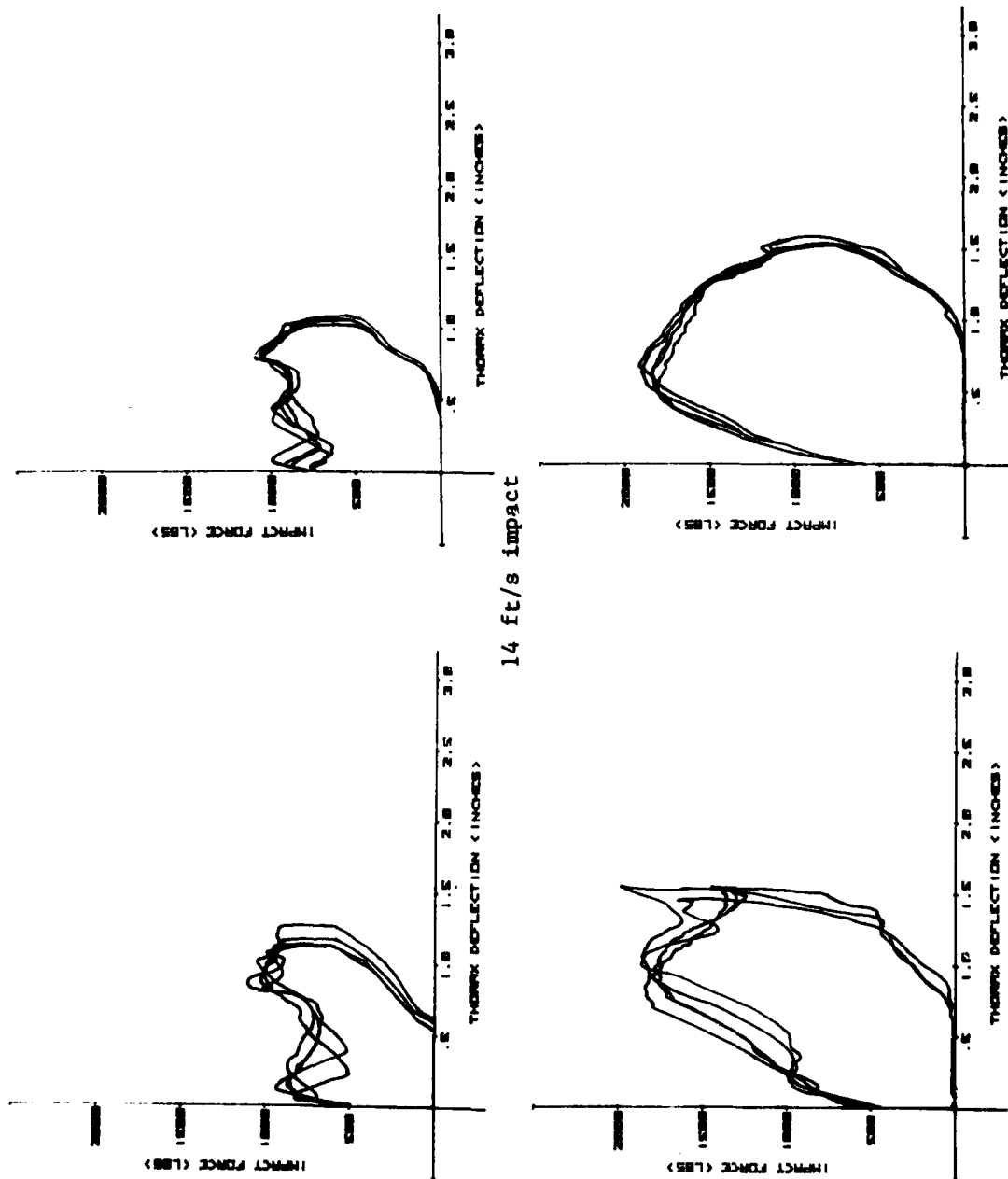


Figure 14. Thorax impact test results on dummy serial number 1 (left) and dummy serial number 2 (right).

USAARL ENERGY-ABSORBING HELICOPTER SEAT TESTS

Three tests were conducted on the third evaluation of a prototype two-passenger helicopter seat in cooperation with the U.S. Army Aeromedical Research Laboratory (USAARL). This seat has potential applications to civil aircraft if it can be made functional, since it has advantages of energy absorption, light weight, easy stowage in a small space, and comfort. Earlier tests showed problems with the Invertube energy absorbers and various structural details. These tests were conducted at 25 g in the forward-facing 30° yaw configuration (Figure 15), at 21 g in the rearward-facing 30° yaw configuration (Figure 16), and at 18 g using the forward-facing seat oriented for lateral impact (Figure 17). The failures of the energy absorbers were again noted, together with other structural failures, including those of the floor-mounted anchorages that would normally be part of the aircraft. Further development of this system is indicated before operational applications for civil aircraft should be considered.

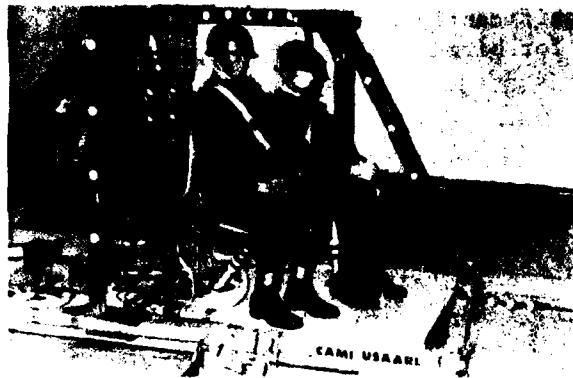


Figure 15. Forward-facing seat, 30° yaw configuration.

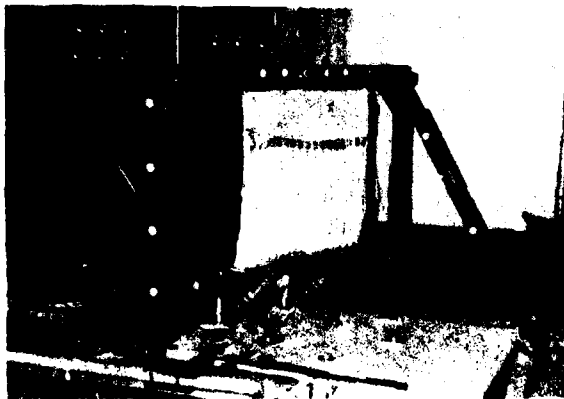


Figure 16. Rearward-facing seat, 30° yaw configuration.

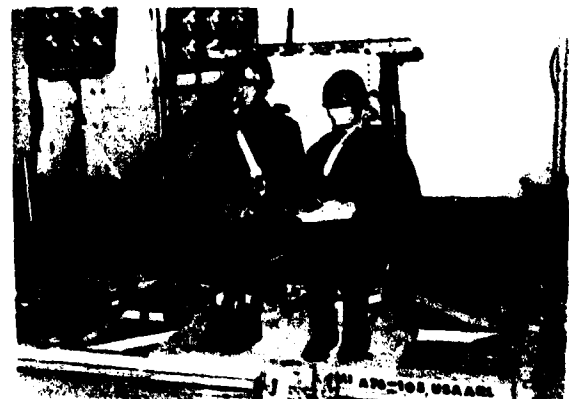


Figure 17. Forward-facing seat, lateral impact configuration.

EFFECT OF PRECRASH DECELERATION ON THE PERFORMANCE OF AN INERTIA REEL

A test program was conducted to provide information on the action of an inertia reel during a crash sequence where the primary crash pulse was preceded by a relatively long-duration, low-level deceleration. A deceleration profile was established to provide approximately 0.6 g for 1 s, immediately followed by a 20-g pulse. A diagonal belt upper torso restraint incorporating a 0.5-g inertia reel and a lapbelt with locking retractor was used for these tests. No significant difference was noted between a restraint system without an inertia reel and a restraint system with an inertia reel. In both instances, the dummy moved forward until it was restrained by the belts during the low-deceleration preliminary impact, slightly preloading the restraint prior to the major crash pulse. These test results do not apply to 3.0-g inertia reel performance.

These tests required a deceleration distance of approximately 34 ft. This distance is significantly greater than the capability of most track facilities designed for biomedical crash injury research.

BELT SLIPPAGE ON COMBINED SHOULDER BELT AND LAPBELT RESTRAINT SYSTEM

Field reports indicated that some restraint systems using ASE A43030 webbing length adjusters (or their equivalent buckle fitting) would not maintain adjustment while in use. Two restraint systems incorporating these fittings were obtained for sled testing to determine if slippage would occur during a simulated crash load. Tests were conducted on a rigid seat with vertical back and horizontal seat pan. Both tight and loose restraint system adjustments were evaluated. The test configuration is shown in Figures 18 and 19, and test parameters are shown in Table 2. Slippage of the webbing through the adjusters was less than 1/2 in in all tests. When the lapbelt was loose, as would occur if the system lost snug adjustment while in use prior to a crash, the test dummy exhibited submarining. It was expected that this tendency would be exaggerated with a nonrigid seat. Loose shoulder straps caused higher deceleration loads on the dummy.

Static tests of tilt lock adjustment angle were made on the ASE A43030 adjusters used on the dynamic tests and on 16 other adjusters taken from CAMI stock. Only the ASE adjusters supplied for the dynamic tests had a lock angle less than 30°. A third ASE A43030 adjuster taken from CAMI stock, superficially identical to the ones used in dynamic tests, had a lock angle of 41°. Closer inspection of these items indicated that the difference in performance may be due to a difference in the sharpness of knurling on the adjuster bar, with sharper knurling producing the greater lock angle.



Figure 18.



Figure 19.

TABLE 2. Restraint Adjustment Sled Test Summary

<u>Test</u>	<u>Subject</u>	<u>Orientation</u>	<u>G</u>	<u>Velocity (ft/s)</u>	<u>Restraint^{1,2,3}</u>	<u>Comment⁴</u>
A77-046	50% M	Forward	1.8	43.5	2	System Ck
A77-047	50% M	Forward	1.8	43.8	2	System Ck
A77-048	50% M	Forward	9.0	44.1	2	System Ck
A77-049	5% F	Forward	9.0	44.8	3	A,C,H
A77-050	5% F	Forward	9.0	44.8	3	A,C,F
A77-051	50% M	Forward	9.0	44.0	3	A,C,
A77-052	50% M	Forward	9.0	43.8	3	B,C
A77-053	5% F	Lateral	2.0	44.8	3	A,C
A77-054	5% F	Lateral	2.0	44.4	3	B,C
A77-055	5% F	Forward	9.0	44.8	3	B,C
A77-056	5% F	Forward	9.0	44.4	3	B,I
A77-057	5% F	Forward	9.0	44.5	3	B,E
A77-058	5% F	Forward	9.0	44.4	3	B,D
A77-059	50% M	Forward	9.0	43.7	1	A,C
A77-060	50% M	Forward	9.0	44.0	1	A,C,G
A77-061	5% F	Forward	9.0	44.5	3	A,C
A77-062	5% F	Forward	9.0	44.4	3	A,I
A77-063	5% F	Forward	9.0	44.5	3	A,E
A77-064	5% F	Forward	9.0	44.6	3	A,D

1. Pacific Scientific Co., 4-Point

2. Pacific Scientific Co., 5-Point

3. American Safety Equipment Corp., 4-Point

4. Comments

A. Lapbelt anchored 3 in below seat pan

B. Lapbelt anchored 2 in above seat pan

C. Restraint straps snug

D. Restraint straps loose

E. Loose lapbelt repositioned by snug
shoulder straps

F. Dummy arm failure

G. Modified restraint to reduce
slippage

H. Camera malfunction

I. Loose shoulder straps, tight
lapbelt

SOMLA VALIDATION TEST DATA

The Seat-Occupant Model: Light Aircraft (SOMLA) computer model was developed by the FAA to assist in the dynamic analysis of seating and restraint systems under crash loading. The initial version of the model is operational and its predictions have been compared with a limited number of sled tests and were found to be reasonably in agreement. These new tests were designed to provide a broader data base for validation of the model and to provide a means of evaluating the model performance during conditions that cause plastic deformation of the seat structure. The first of this series used a rigid seat pan and seat back with deformable seat legs and back-to-pan joint. At least 10 tests at two levels of deceleration were conducted in two configurations, forward-facing (Figure 20) and combined forward- and downward-loading (Figure 21). The results of these tests (mean values and standard deviations) are shown for the forward-facing, low-deceleration tests in Figure 22; for the forward-facing, higher deceleration tests in Figure 23; for the combined loading, low-deceleration tests in Figure 24; and for the combined loading, higher deceleration tests in Figure 25.



Figure 20. Forward-facing test configuration.

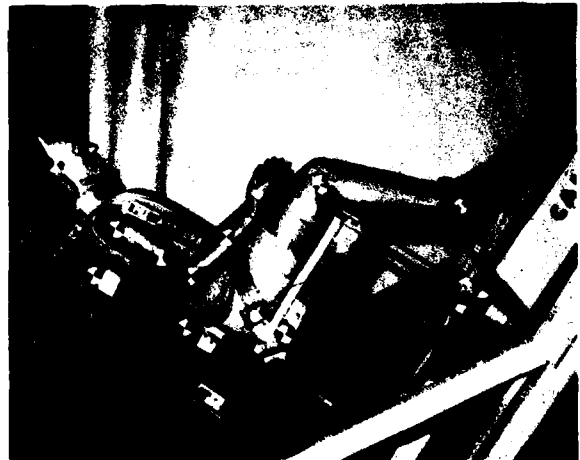


Figure 21. Combined loading test configuration.

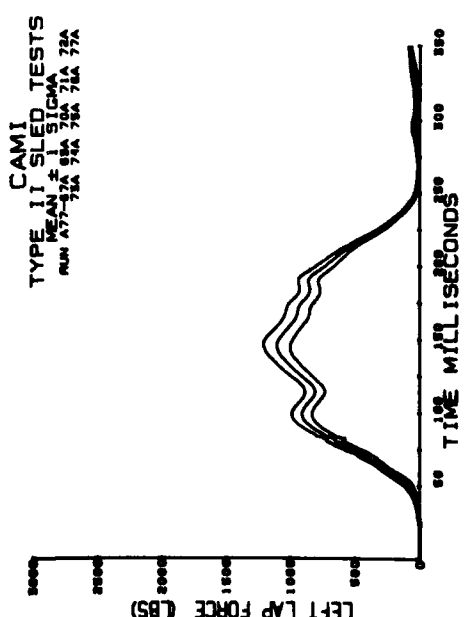
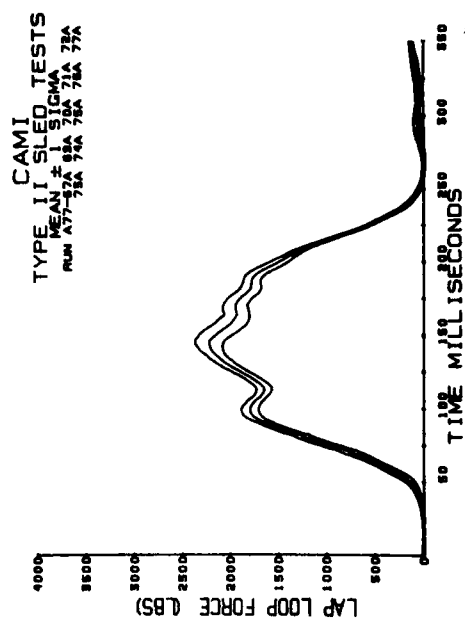
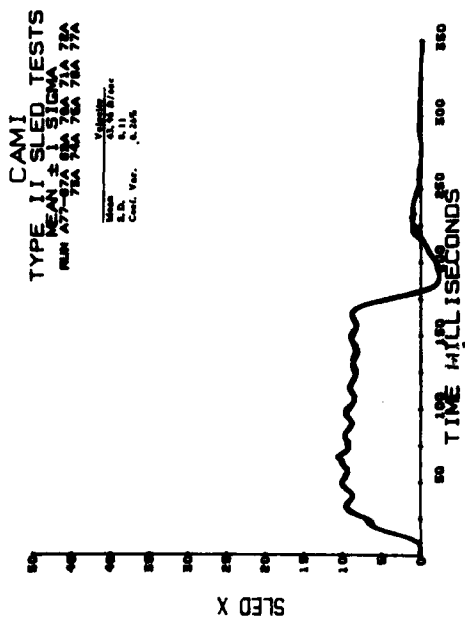
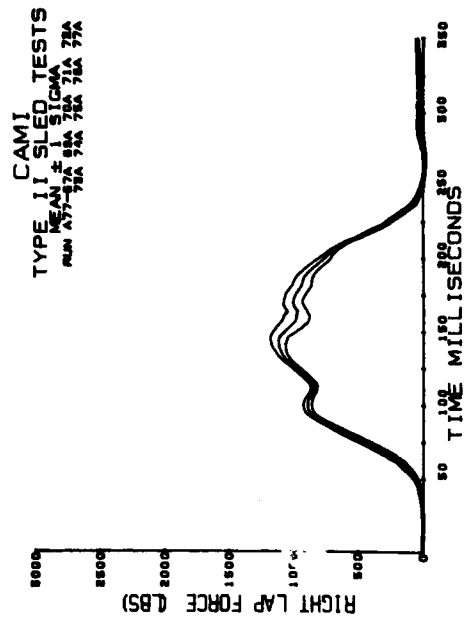


Figure 22. Sled deceleration and lapbelt loads.

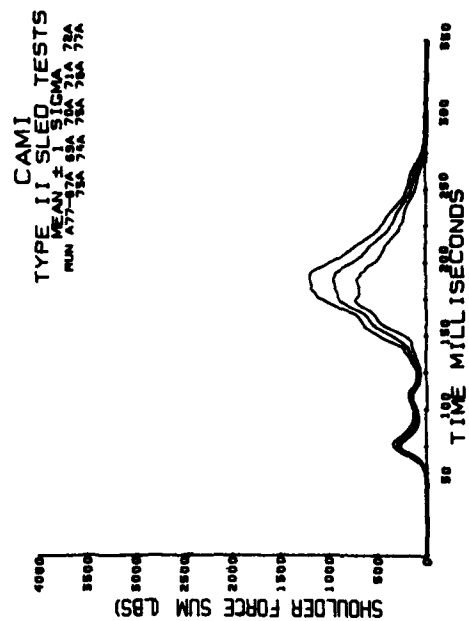
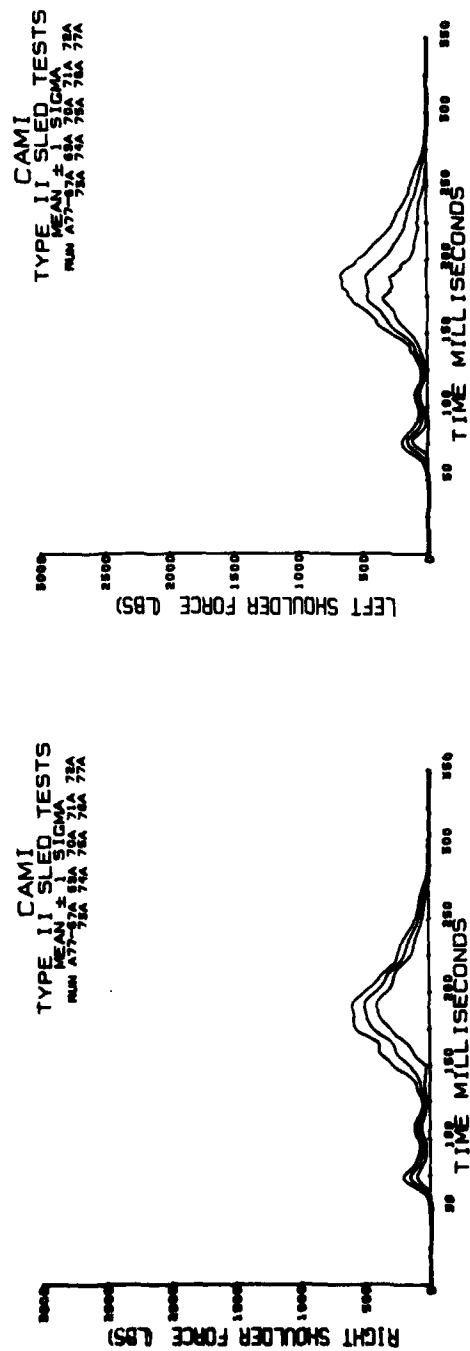


Figure 22. (continued). Shoulder belt loads.

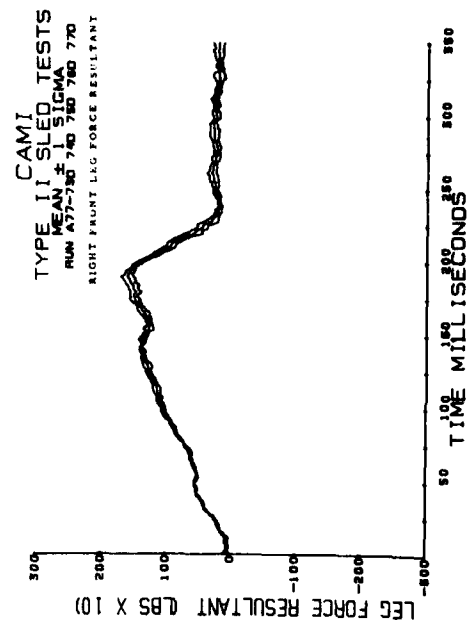
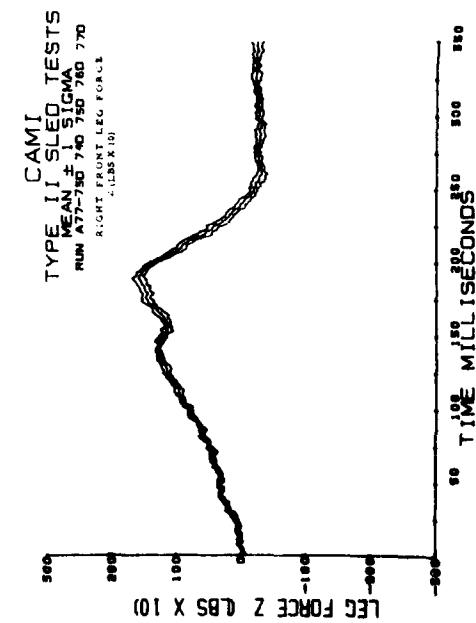
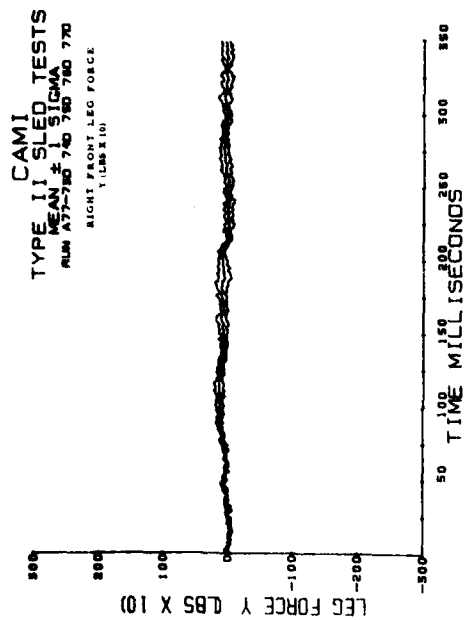
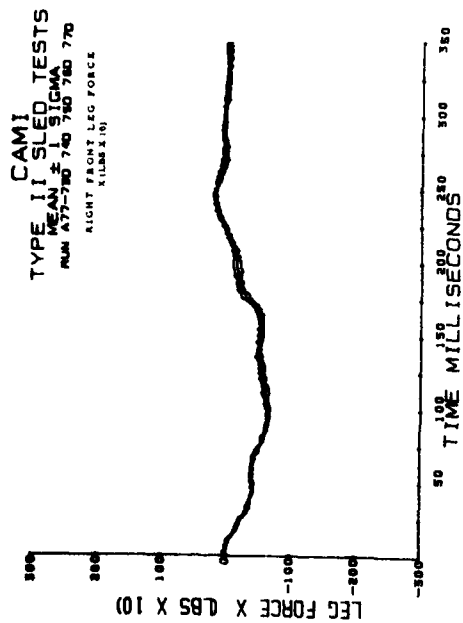


Figure 22. (continued). Right front seat leg loads.

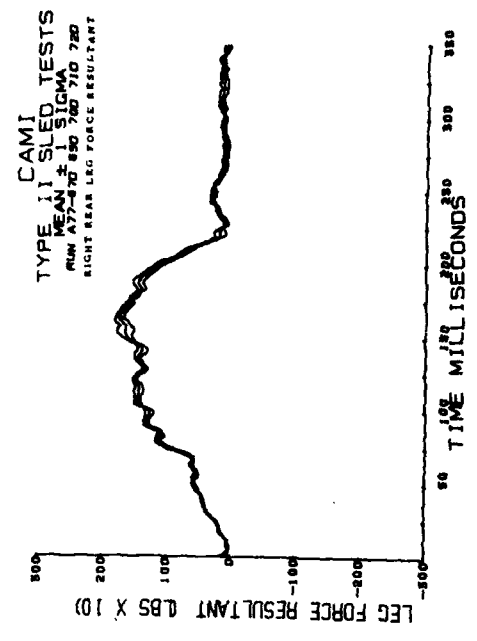
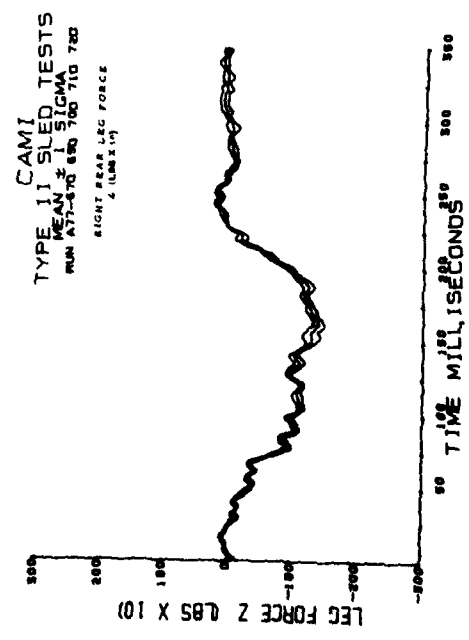
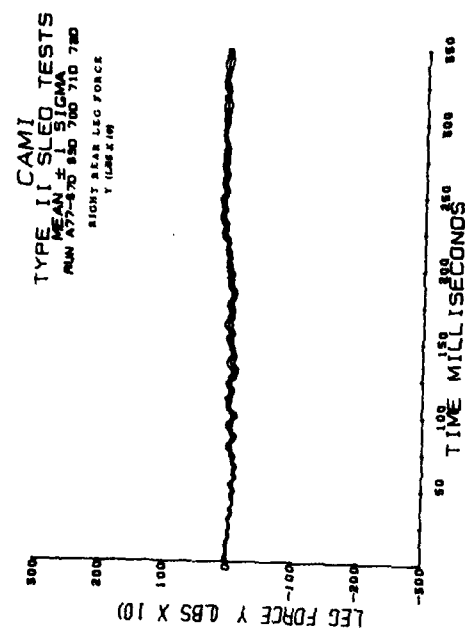
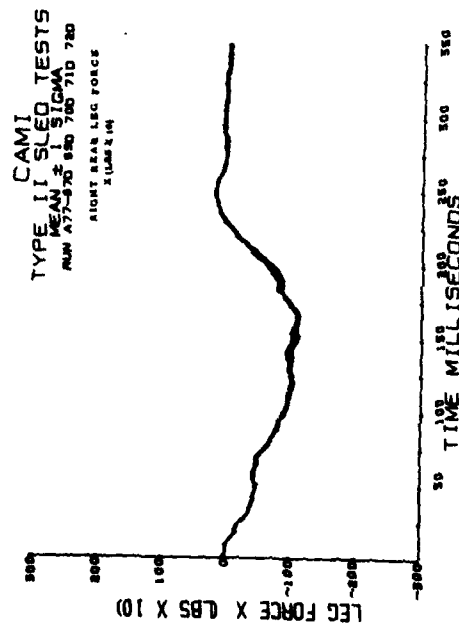


Figure 22. (continued). Right rear seat leg loads.

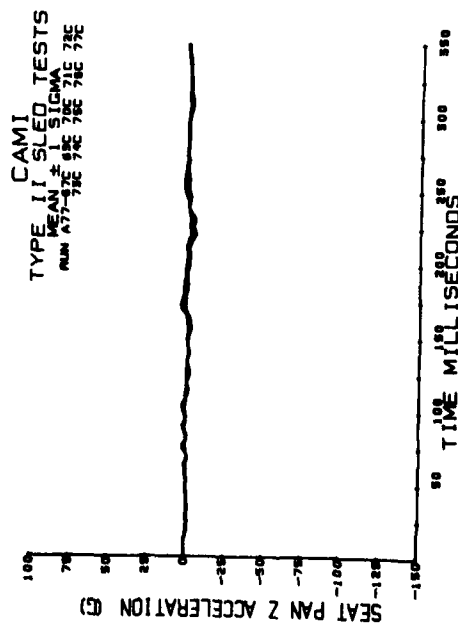
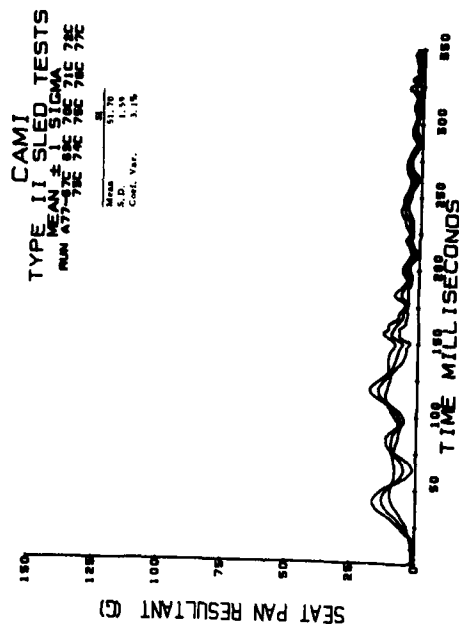
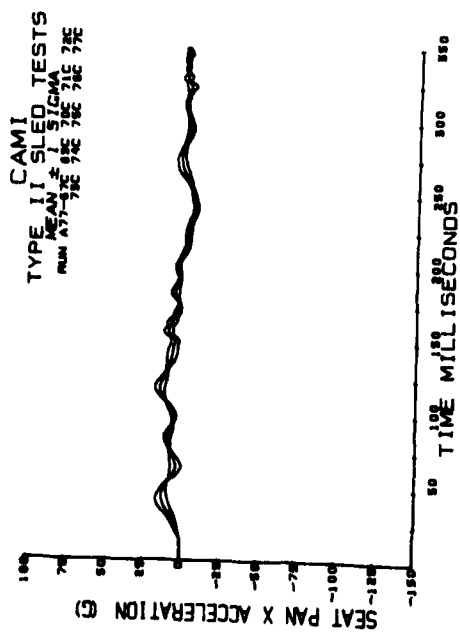
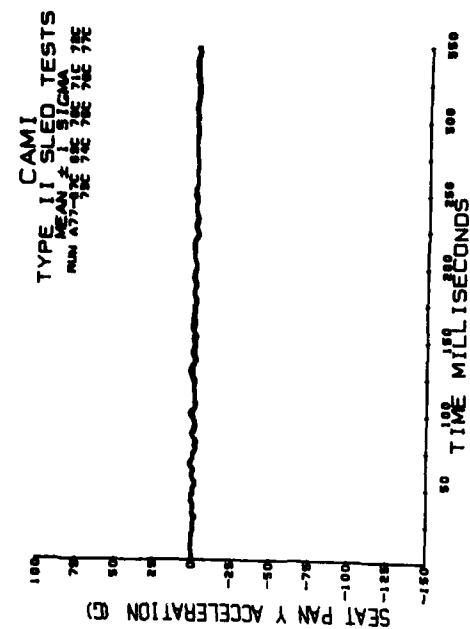


Figure 22. (continued). Seat pan acceleration.

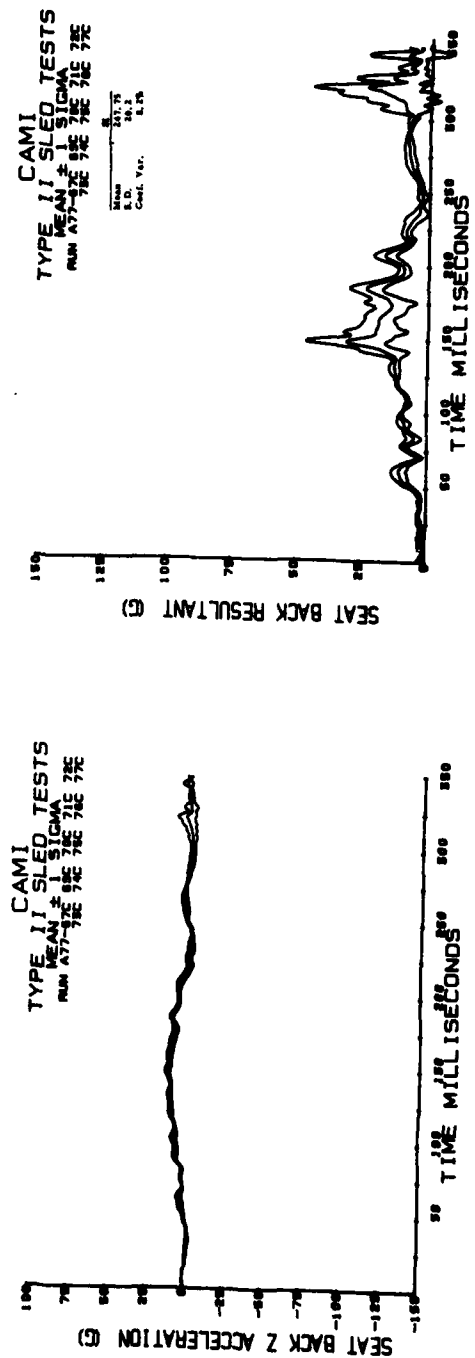
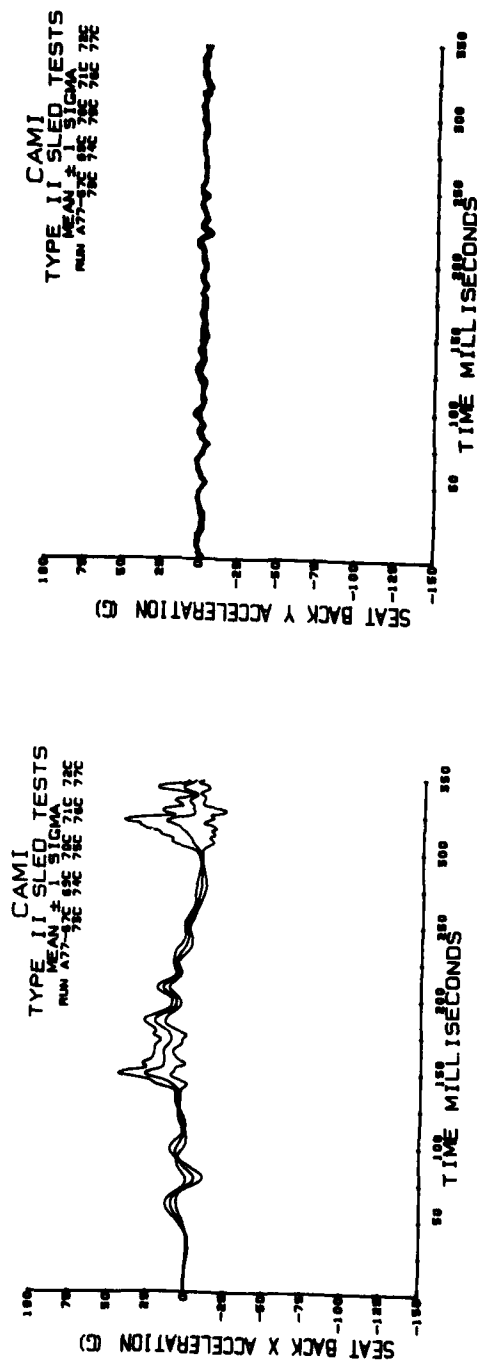


Figure 22. (continued). Seat back acceleration.

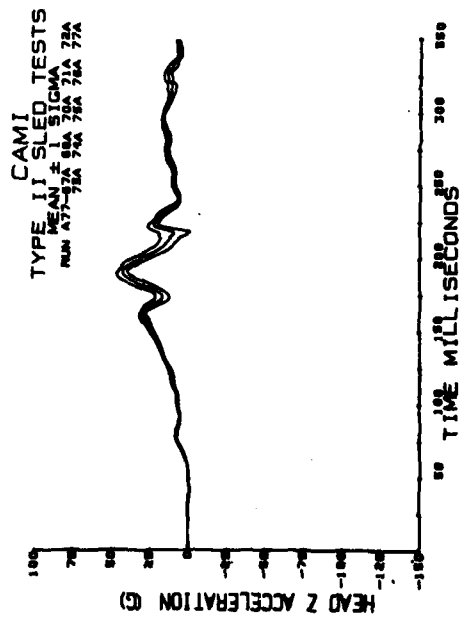
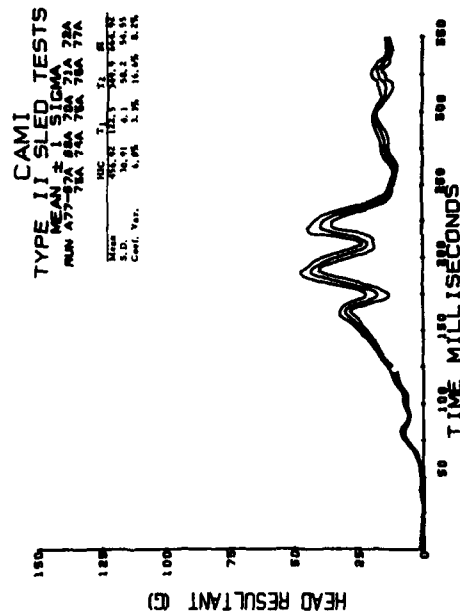
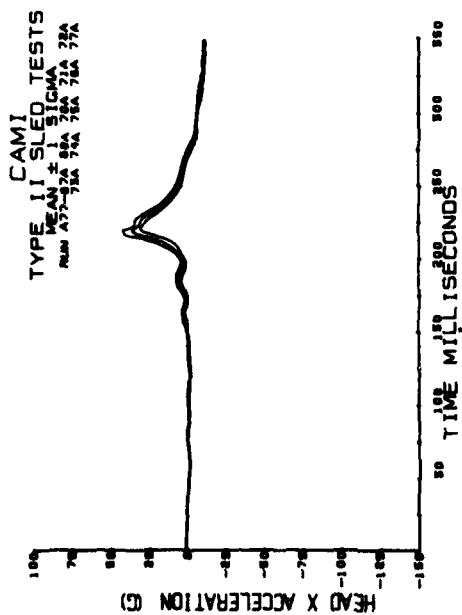
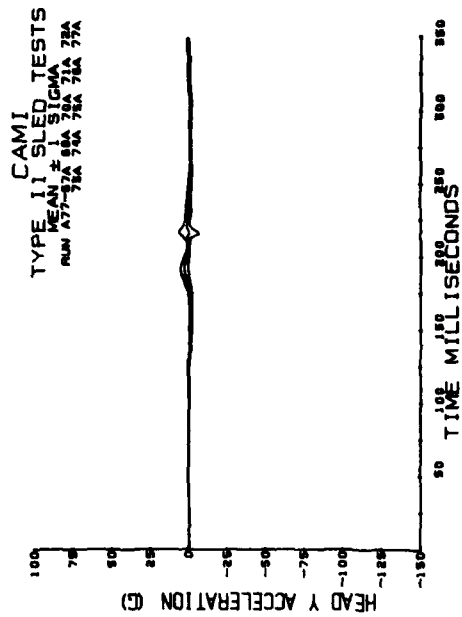


Figure 22. (continued). Head acceleration.

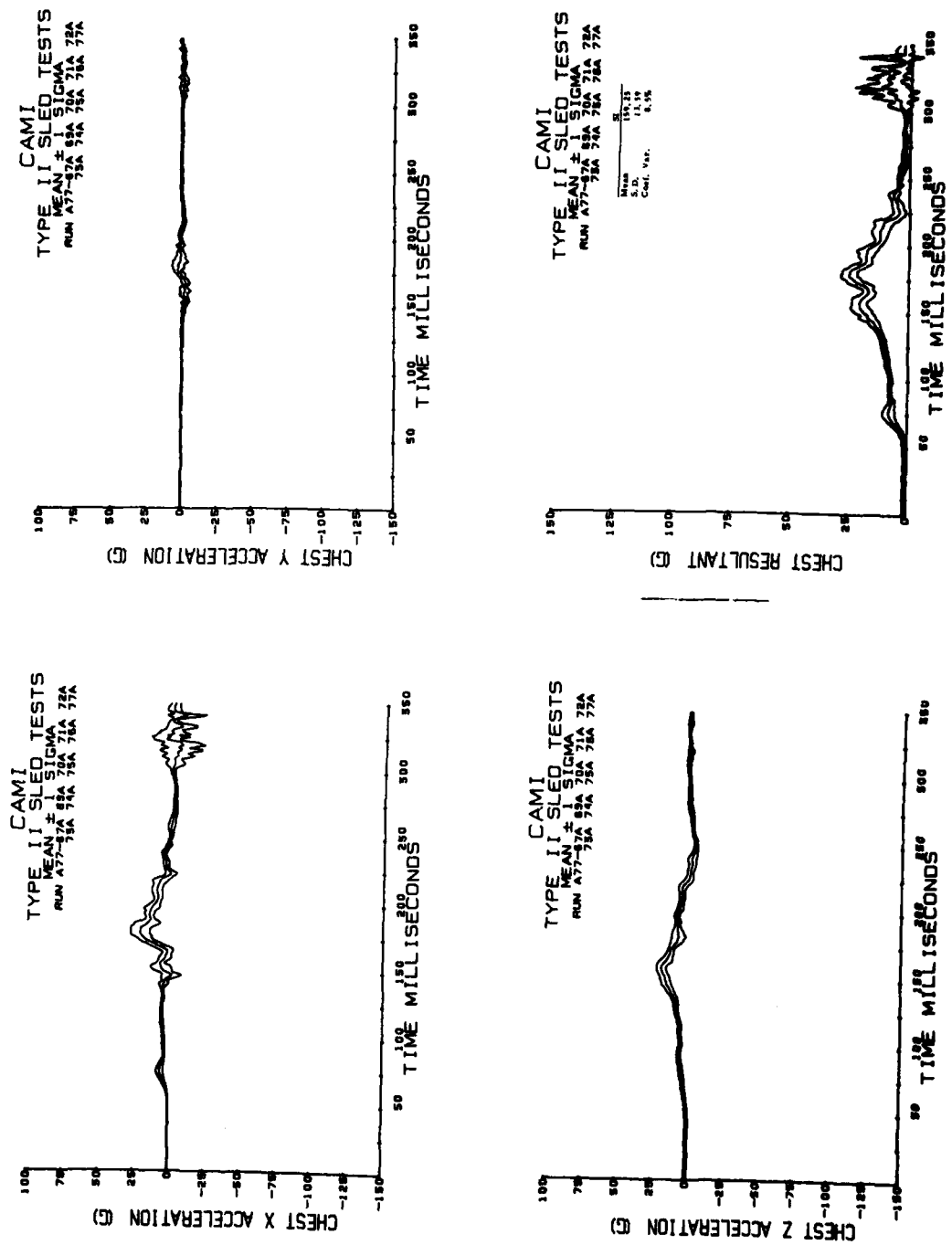


Figure 22. (continued). Chest acceleration.

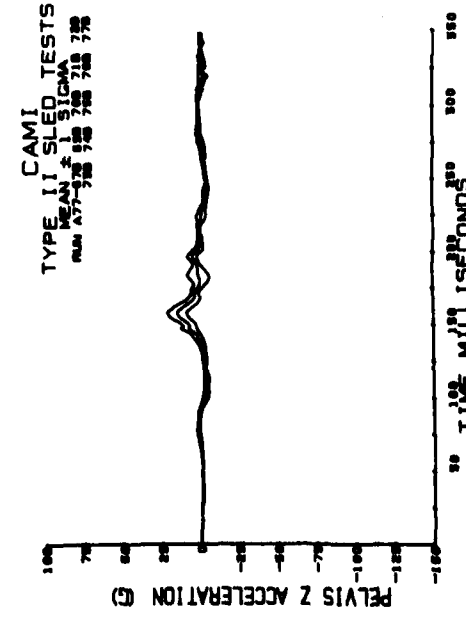
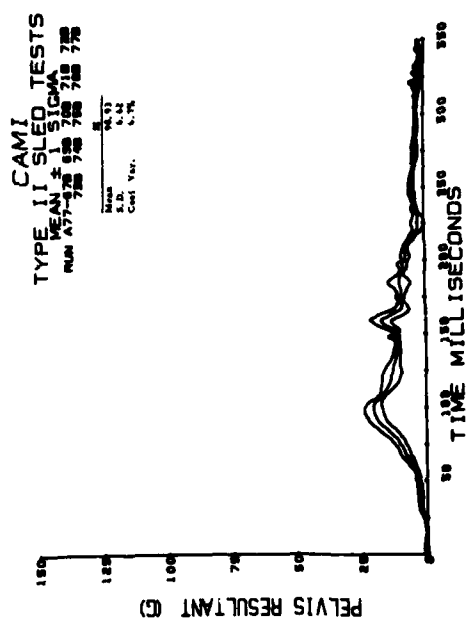
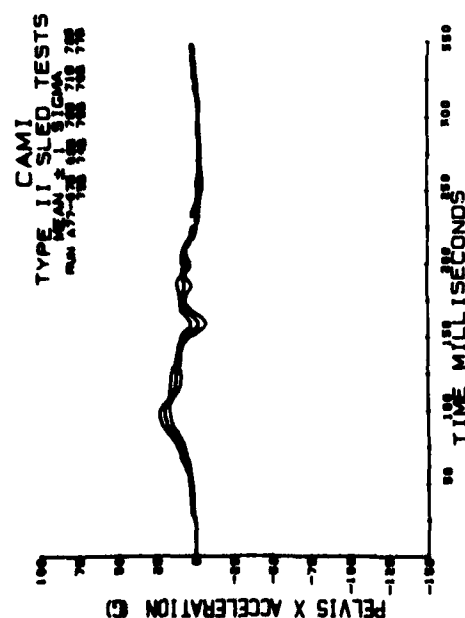
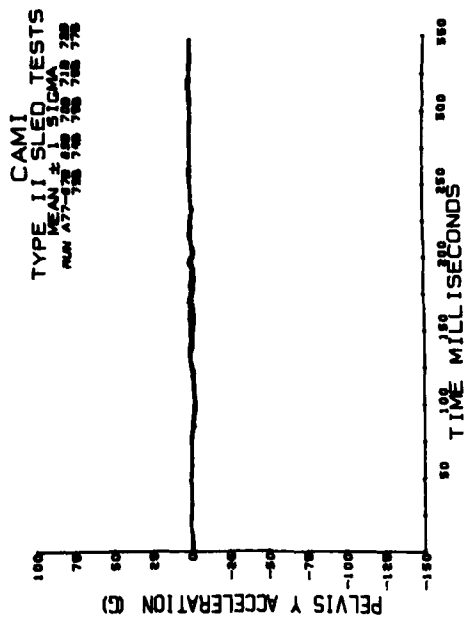


Figure 22. (continued). Pelvis acceleration.

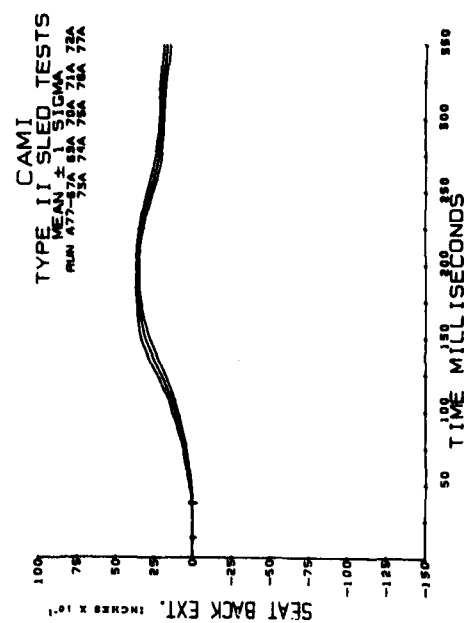
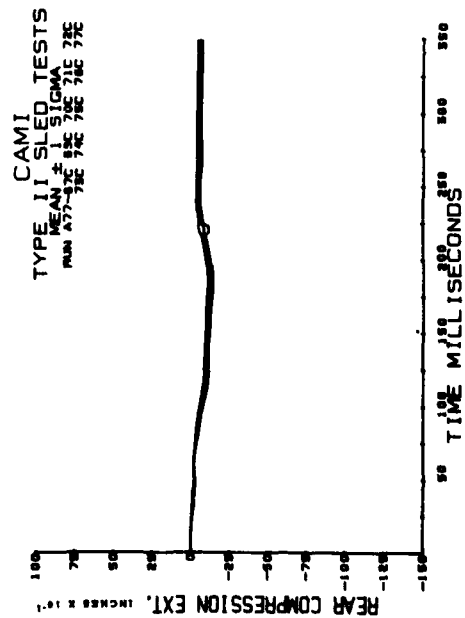
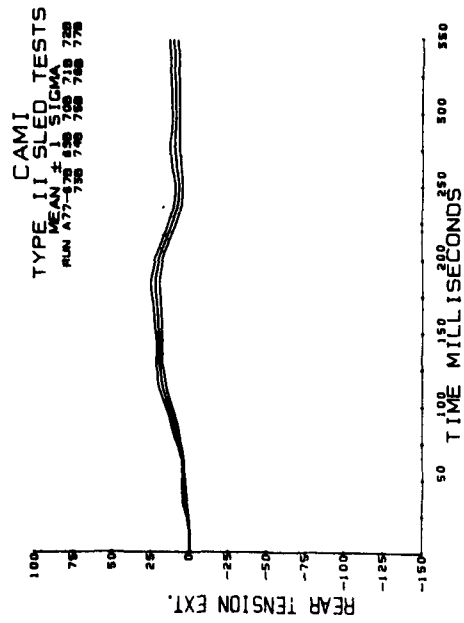
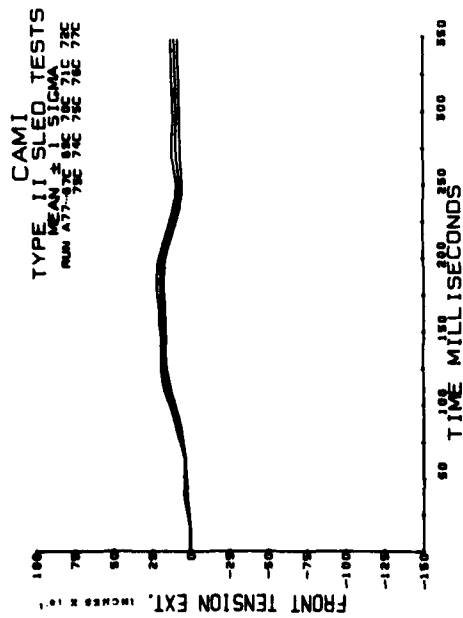
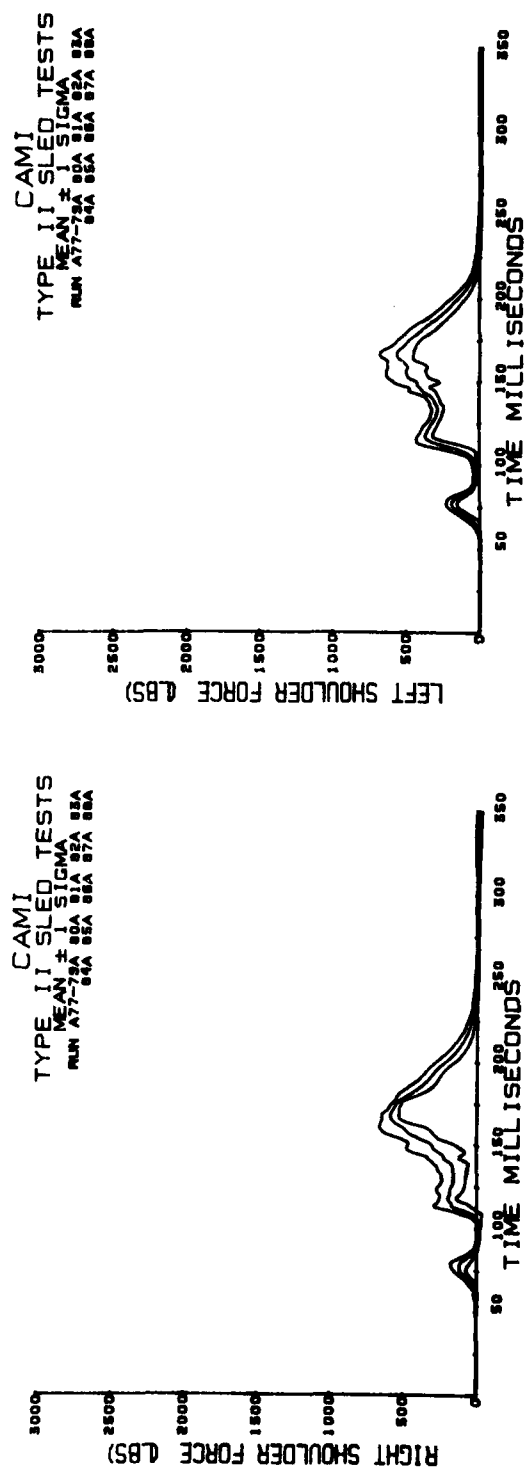


Figure 22. (continued). Seat extensometer data.



CAMI
TYPE II SLED TESTS
MEAN \pm 1 SIGMA
RUN A77-73A 80A 81A 82A
84A 85A 86A 87A 88A

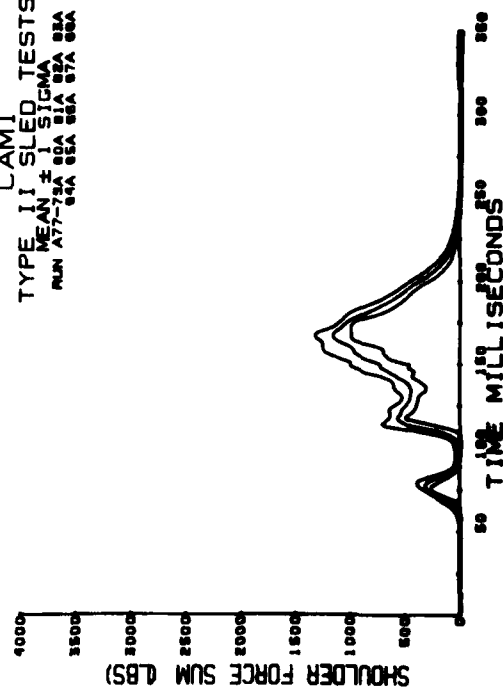


Figure 23. (continued). Shoulder belt loads.

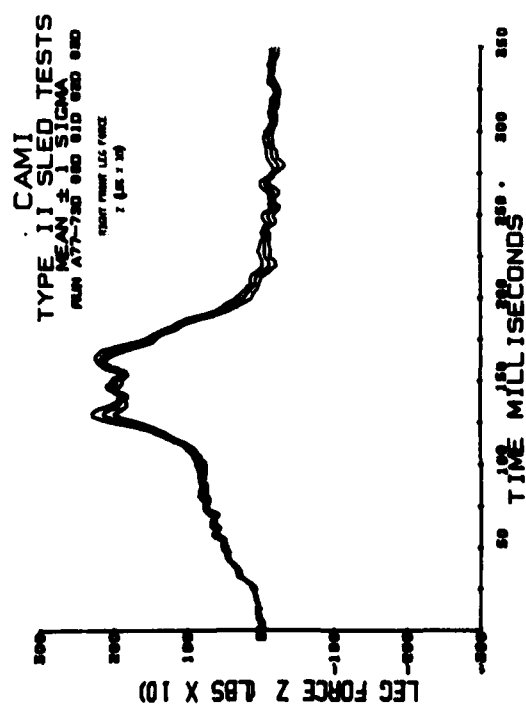
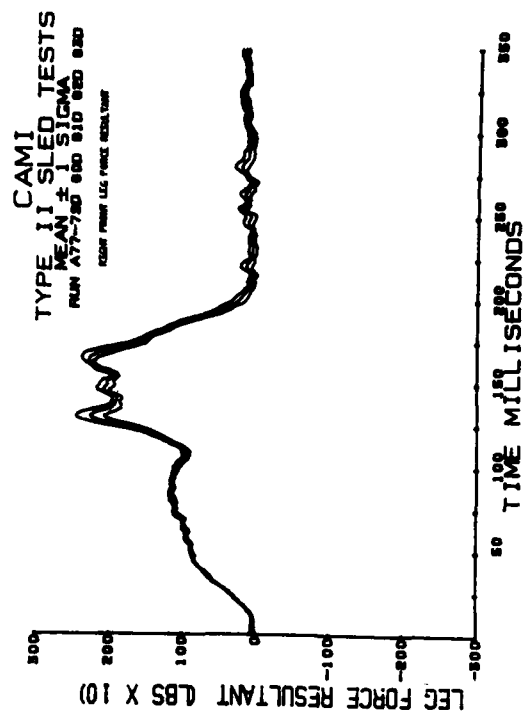
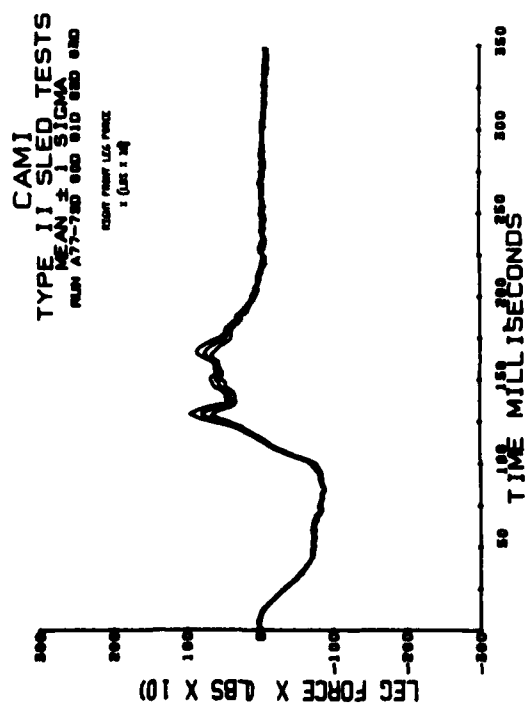
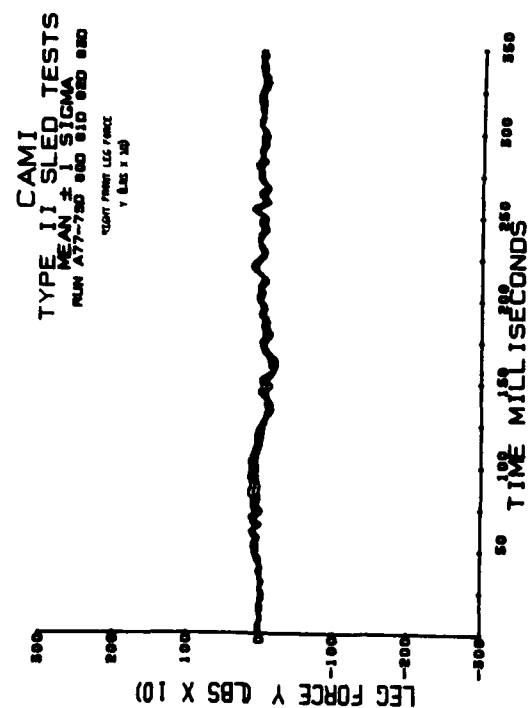


Figure 23. (continued). Right front seat leg loads.

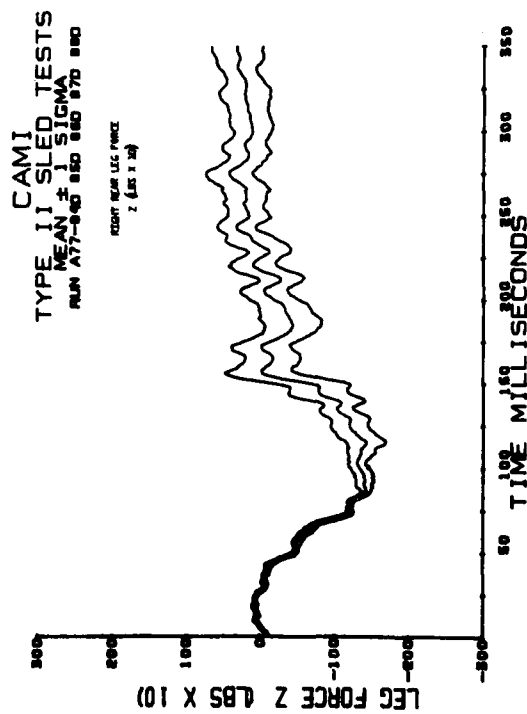
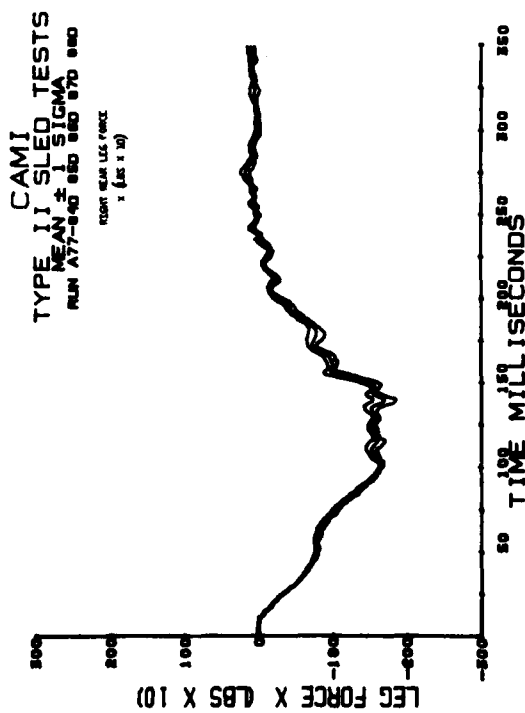
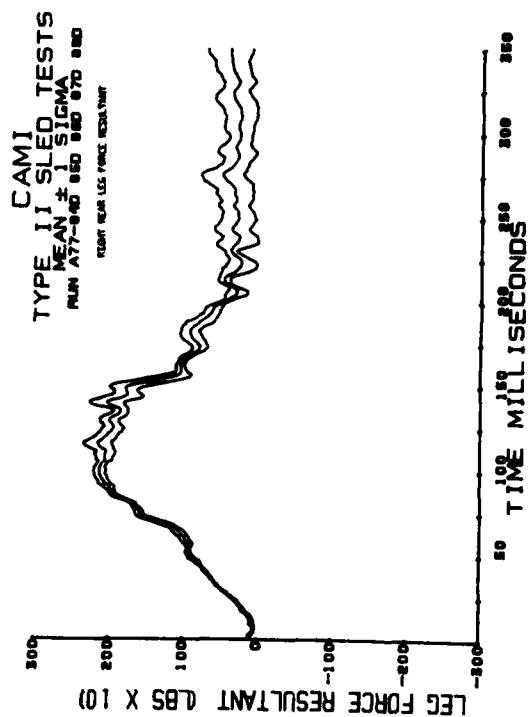
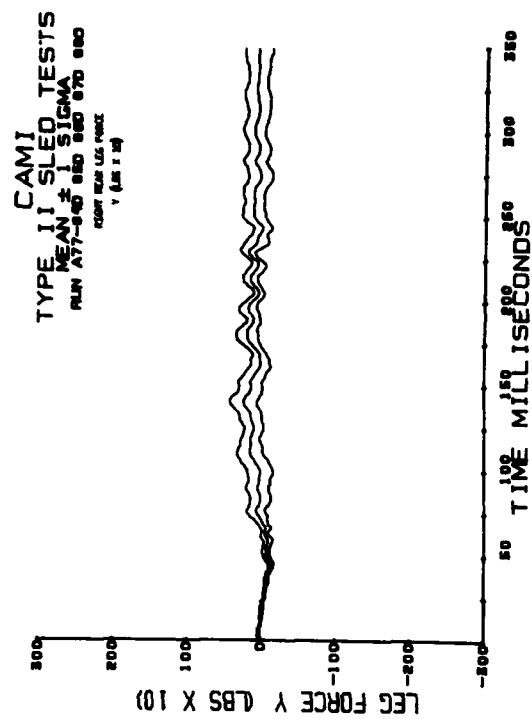


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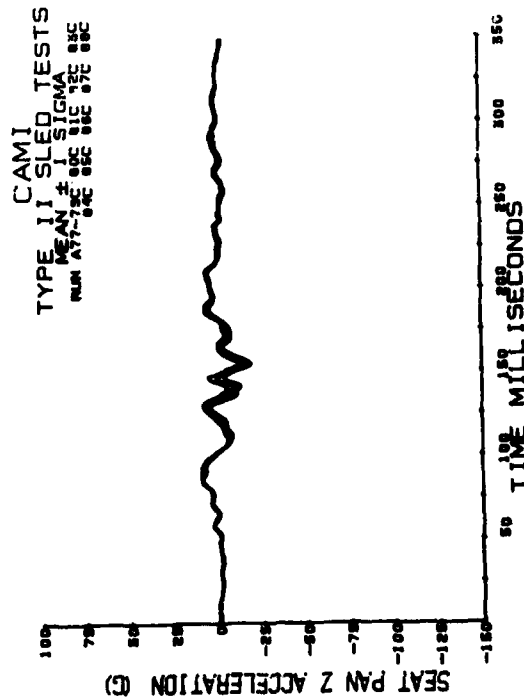
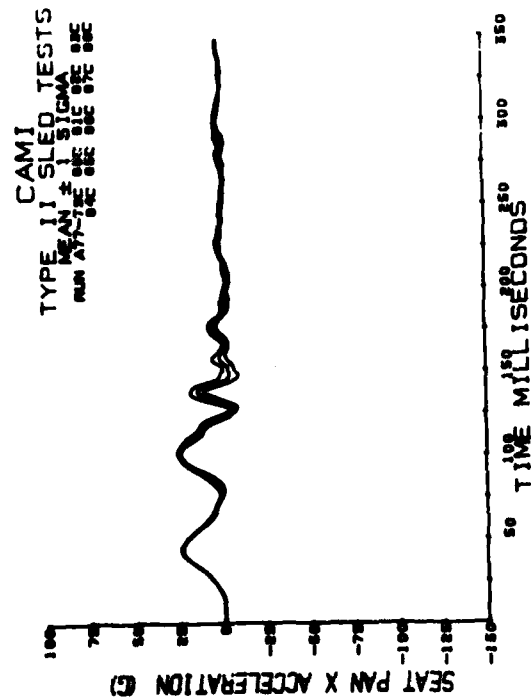


Figure 23. (continued). Seat pan acceleration.

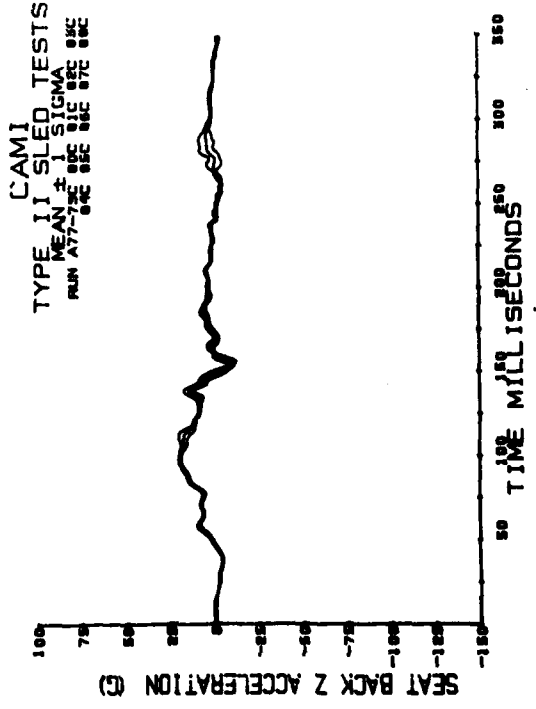
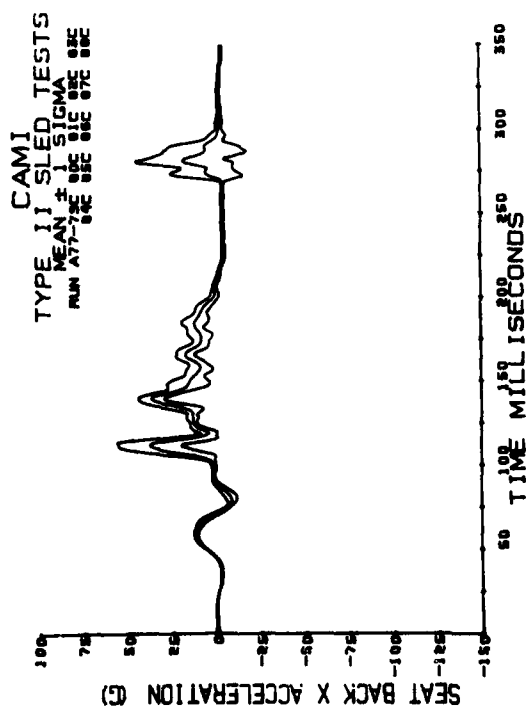
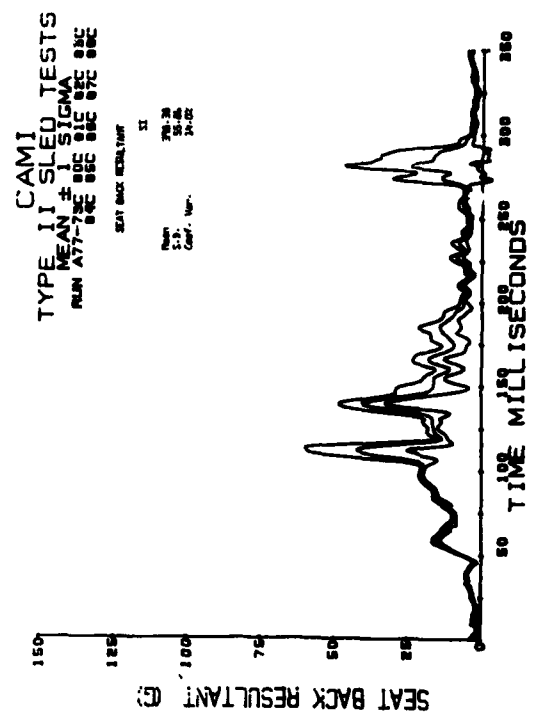
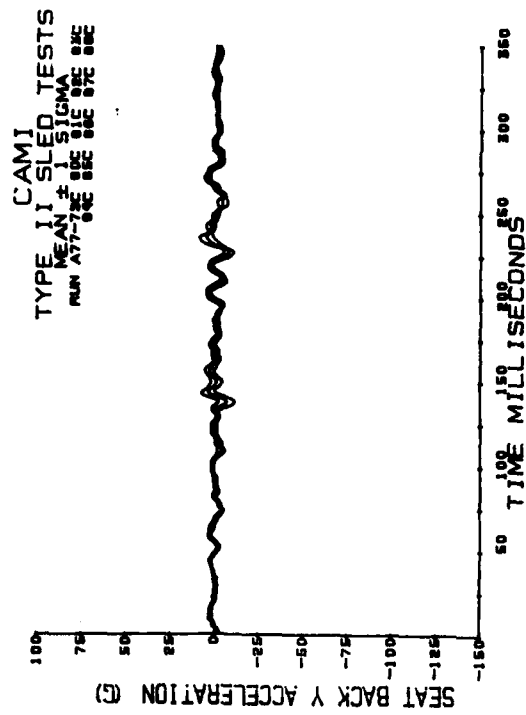


Figure 23. (continued). Seat back acceleration.

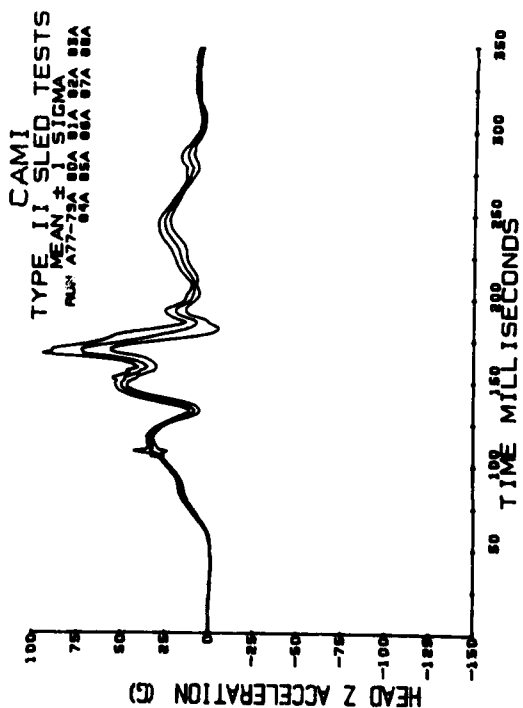
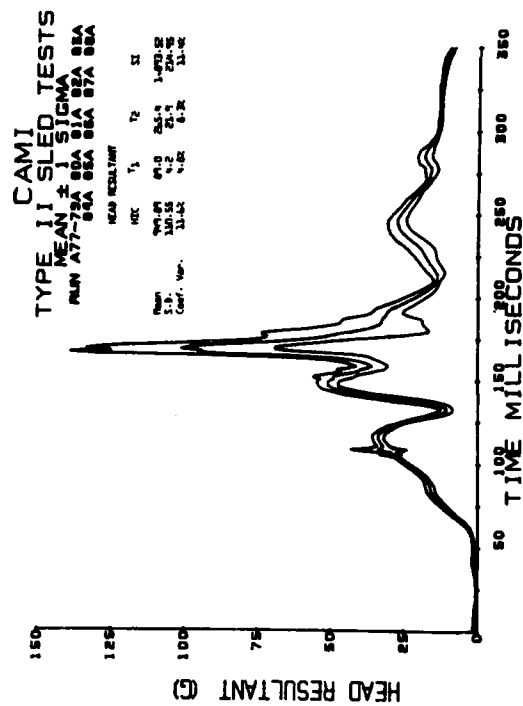
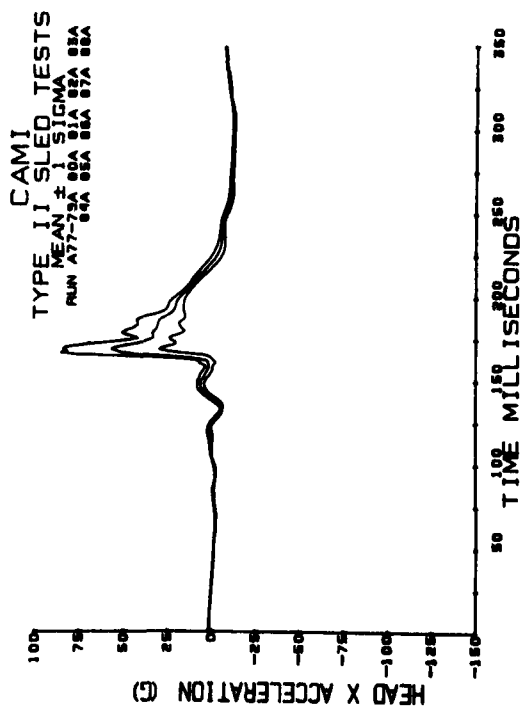
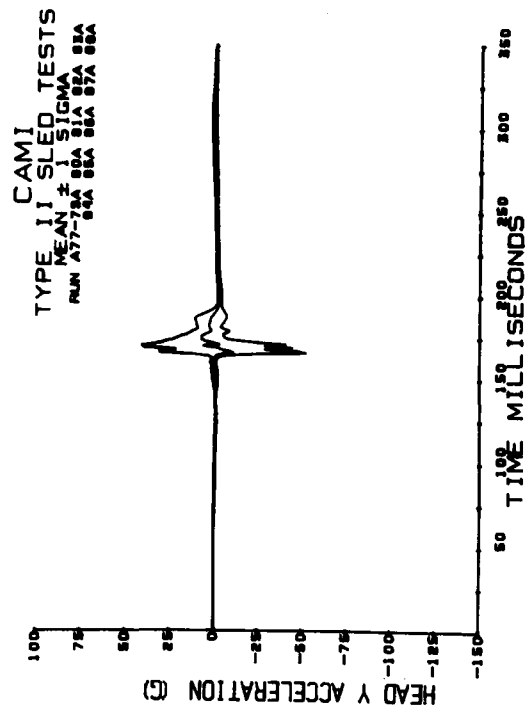


Figure 23. (continued). Head acceleration.

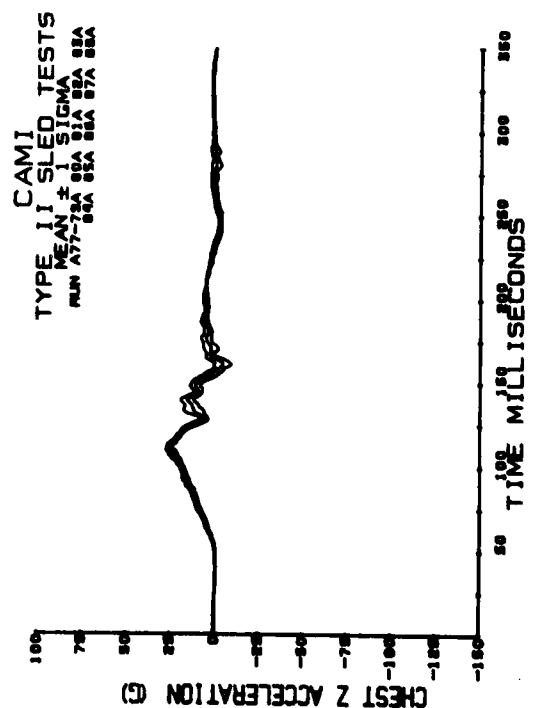
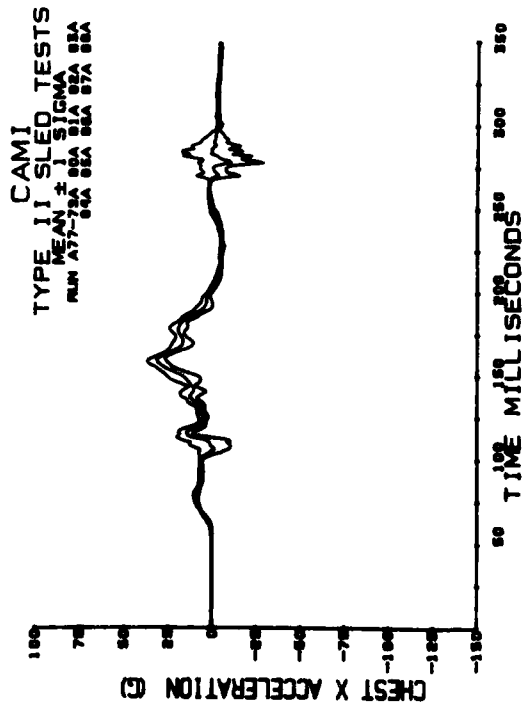
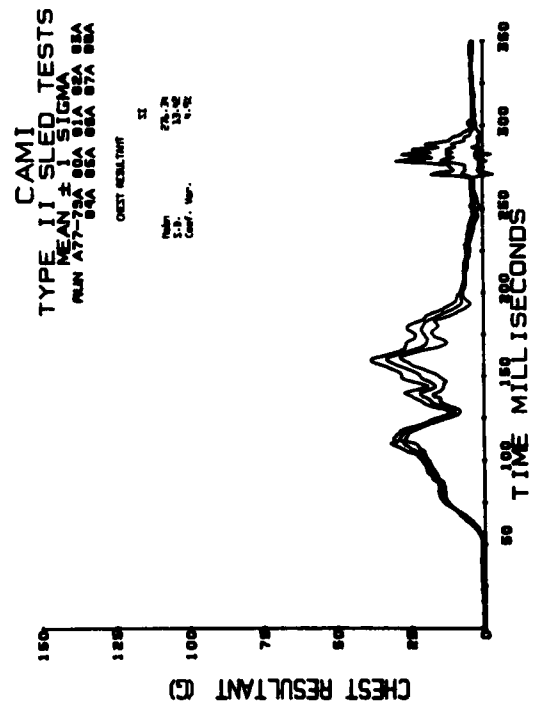
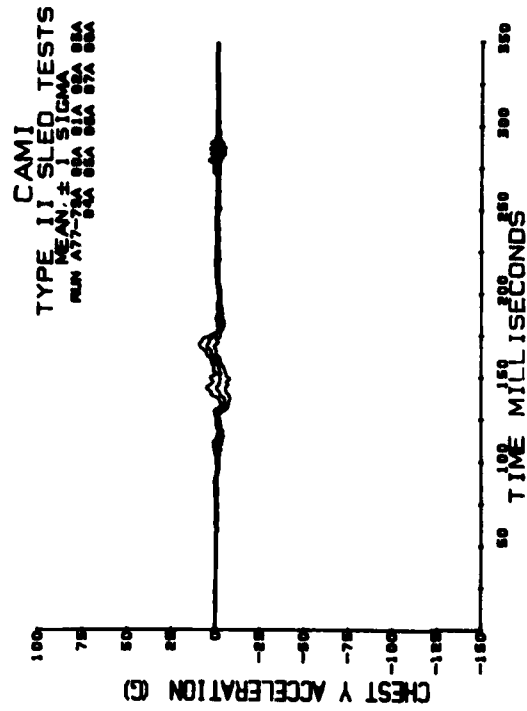


Figure 23. (continued). Chest acceleration.

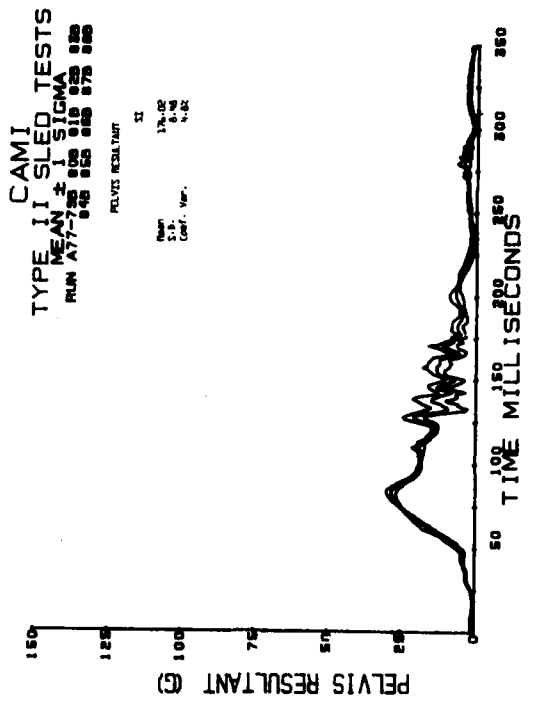
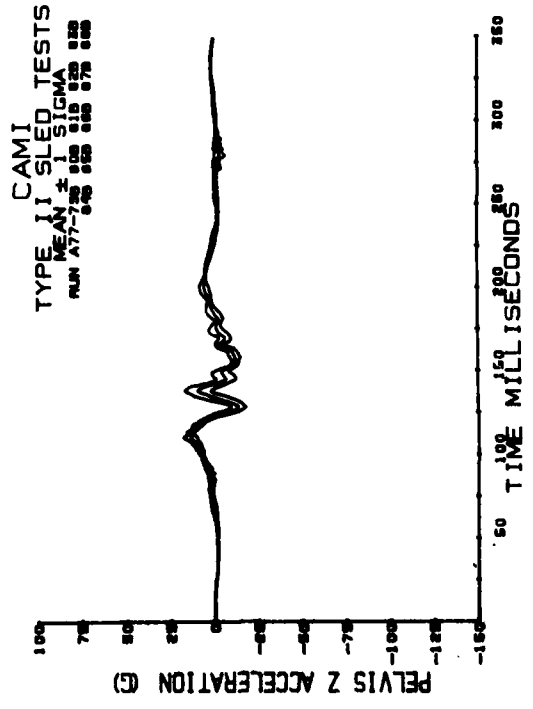
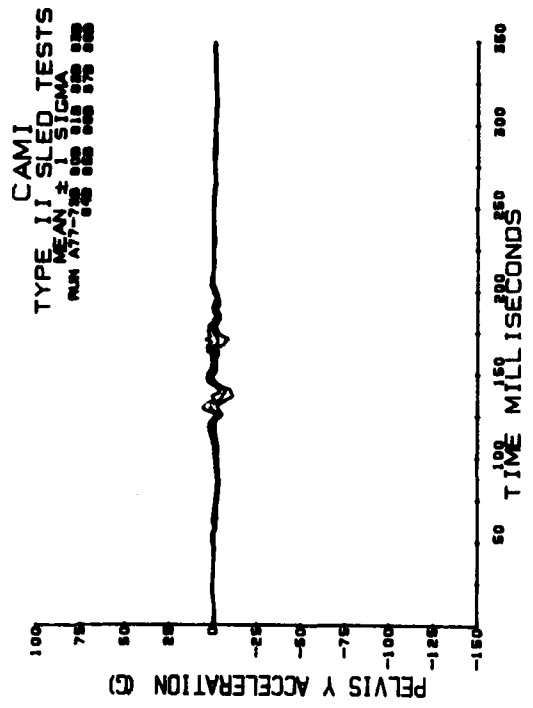
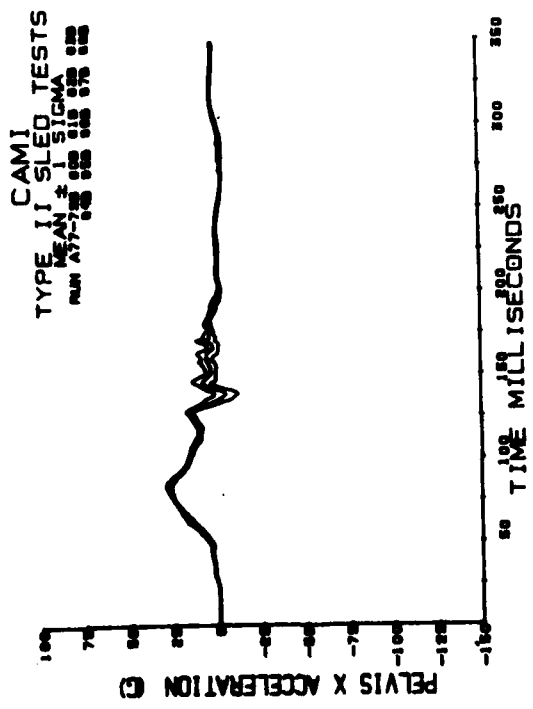


Figure 23. (continued). Pelvis acceleration.

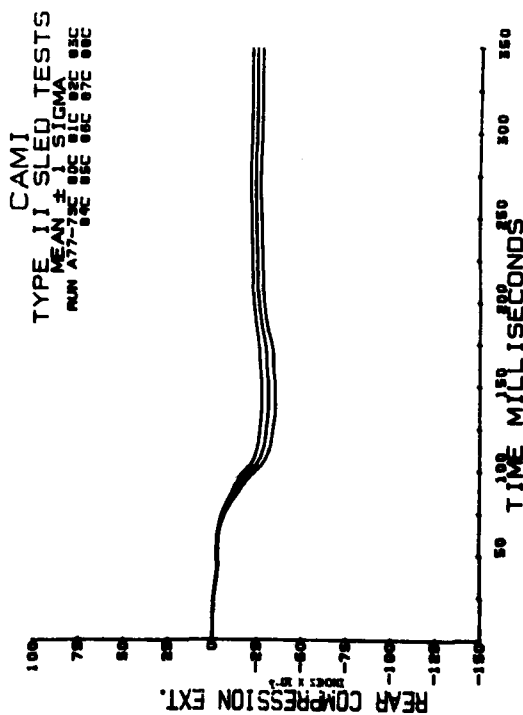
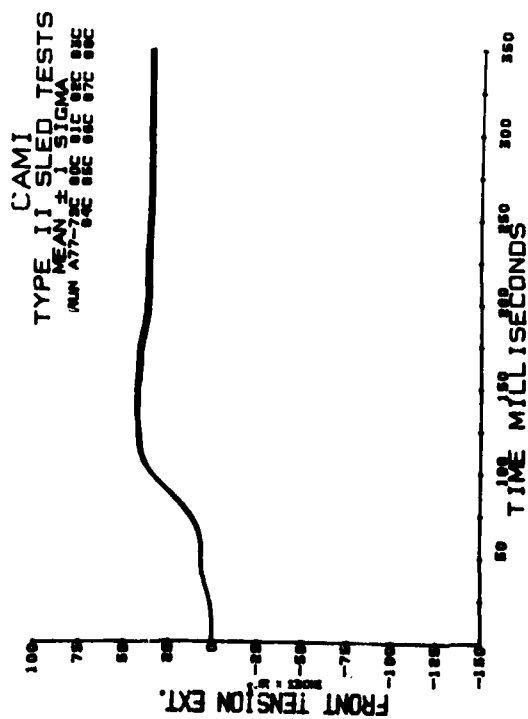
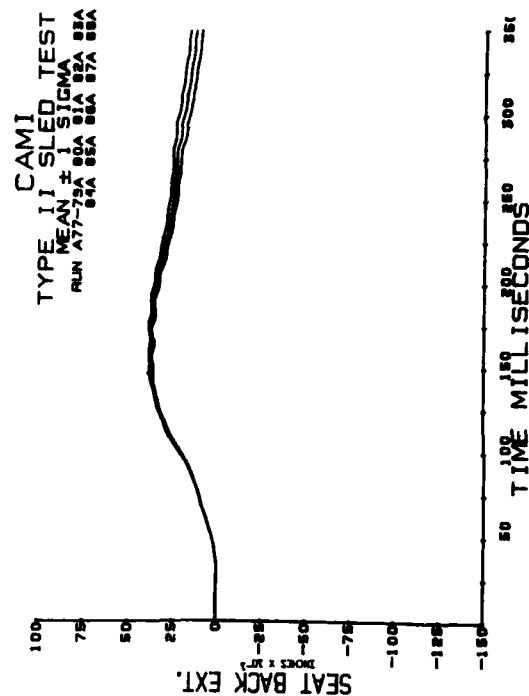
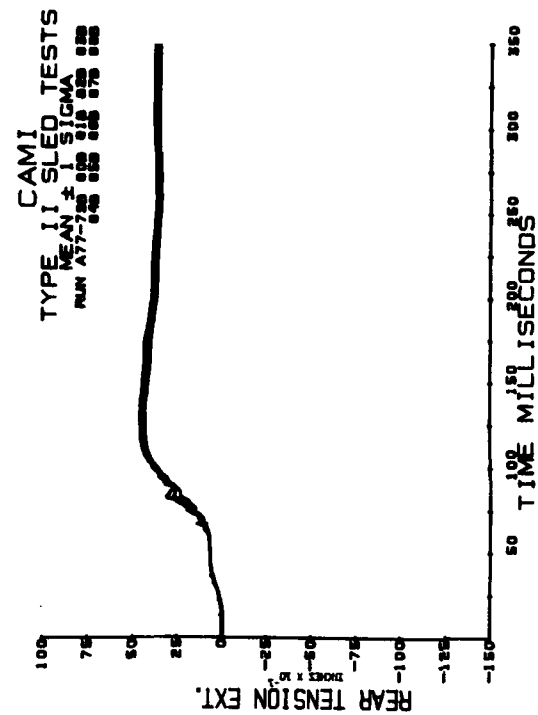


Figure 23. (continued). Seat extensometer data.

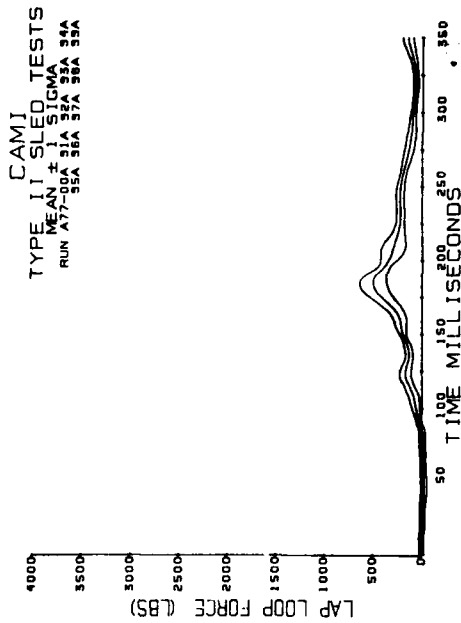
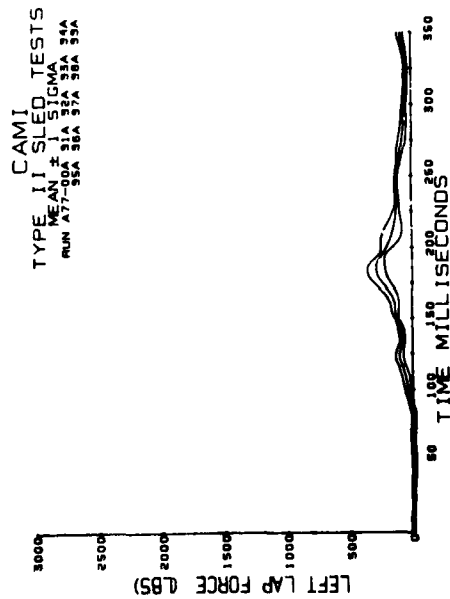
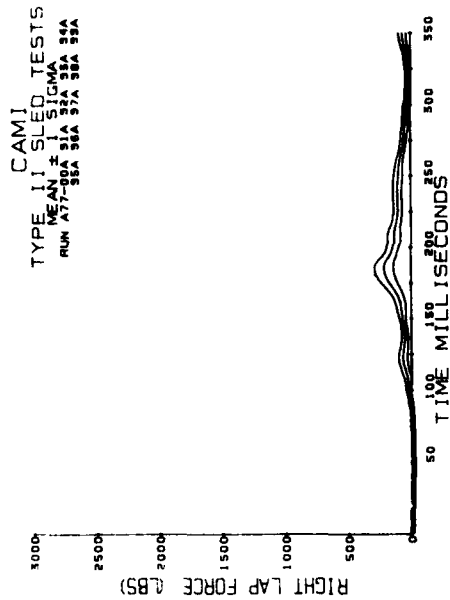
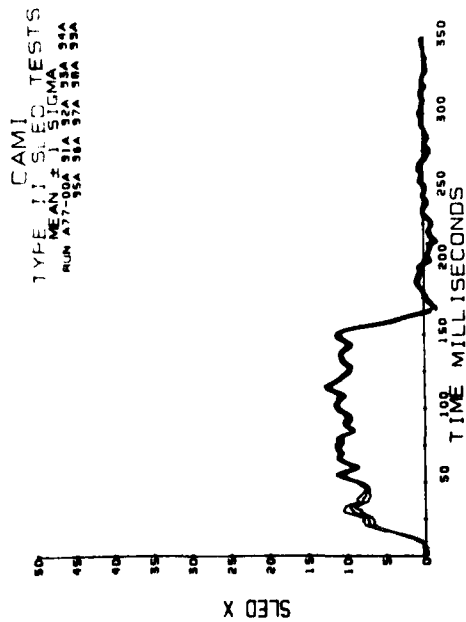


Figure 24. Sled deceleration and lapbelt loads.

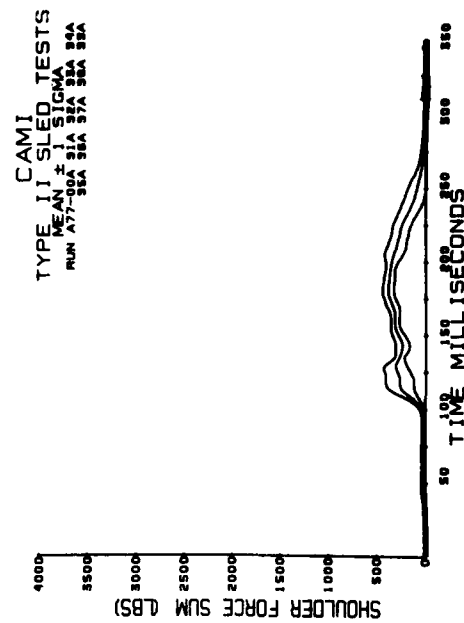
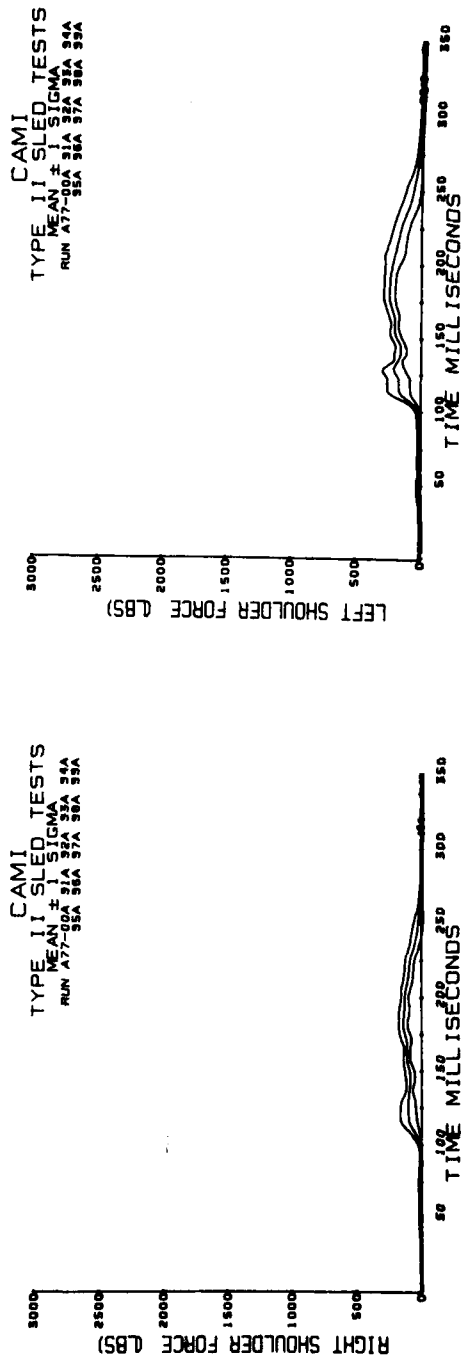


Figure 24. (continued). Shoulder belt loads.

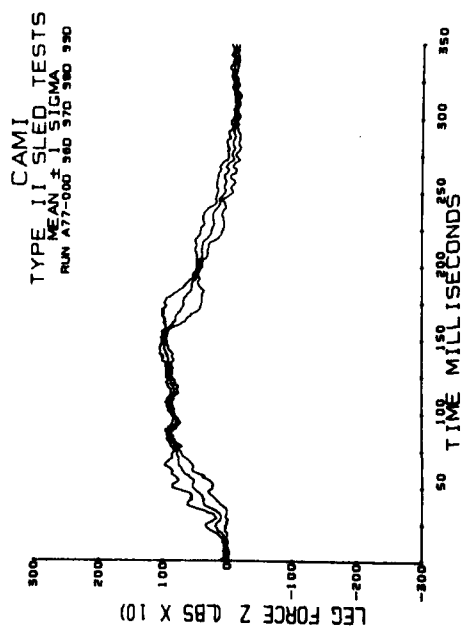
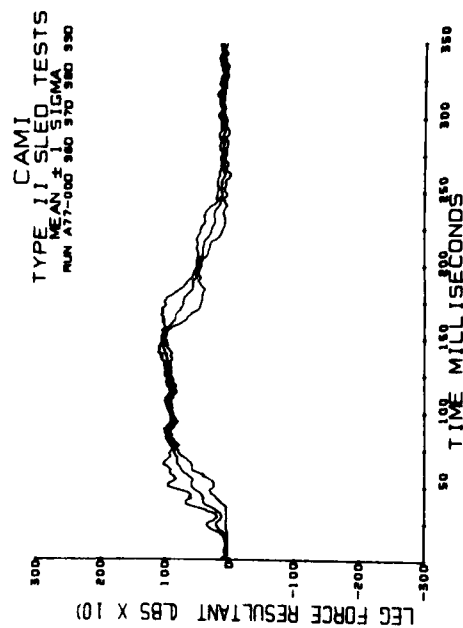
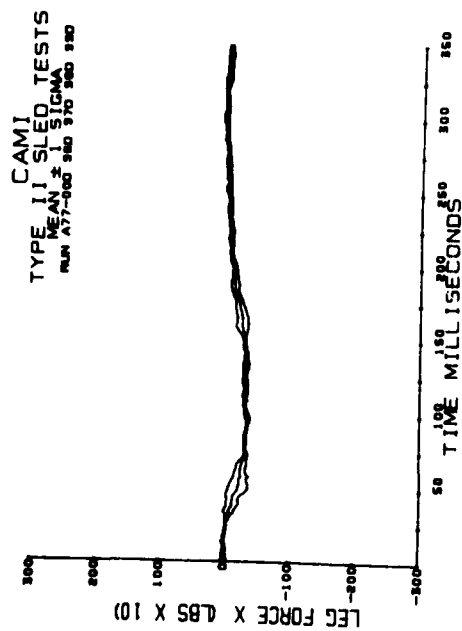
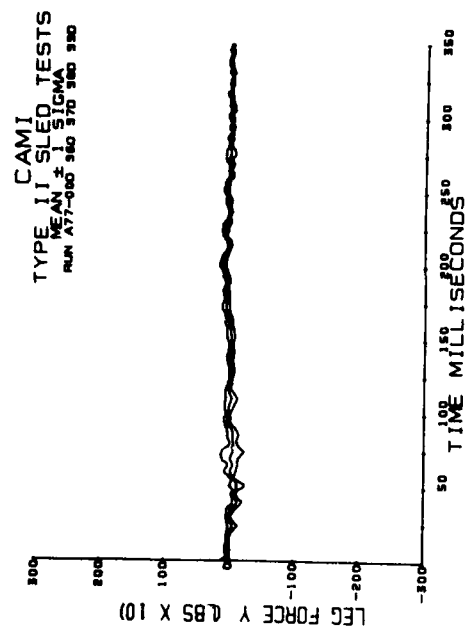


Figure 24. (continued). Right front seat leg loads.

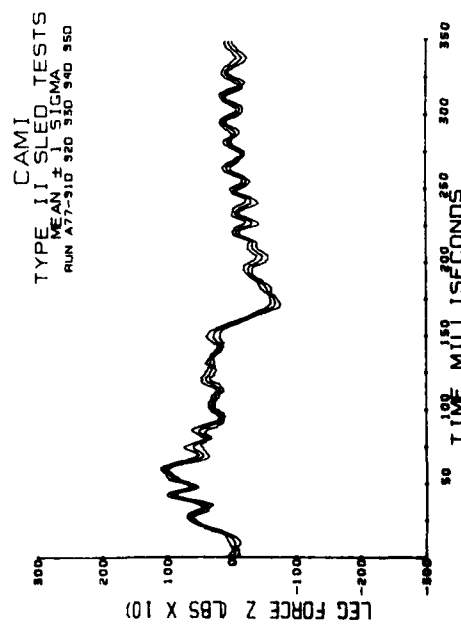
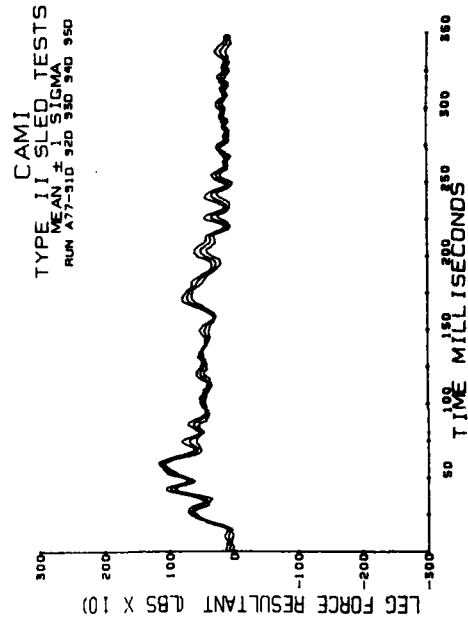
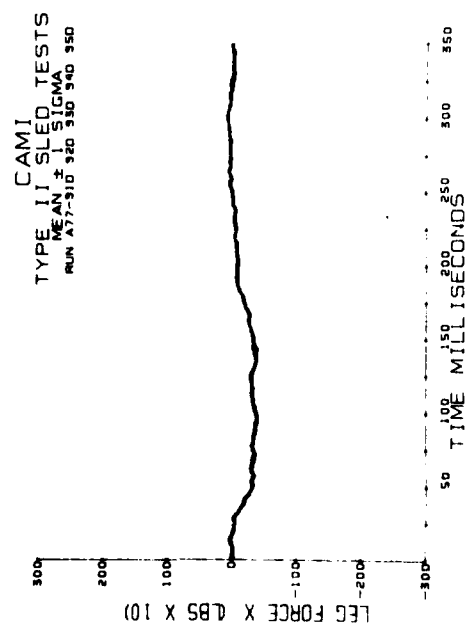
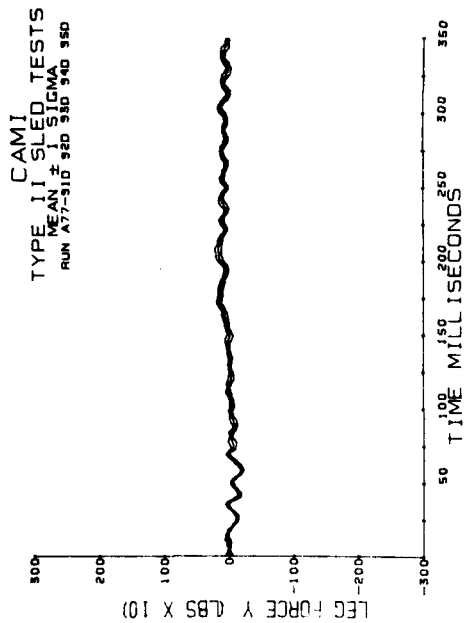


Figure 24. (continued). Right rear seat leg loads.

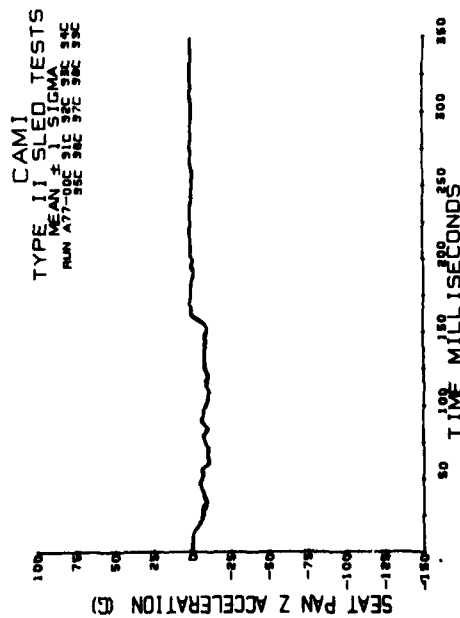
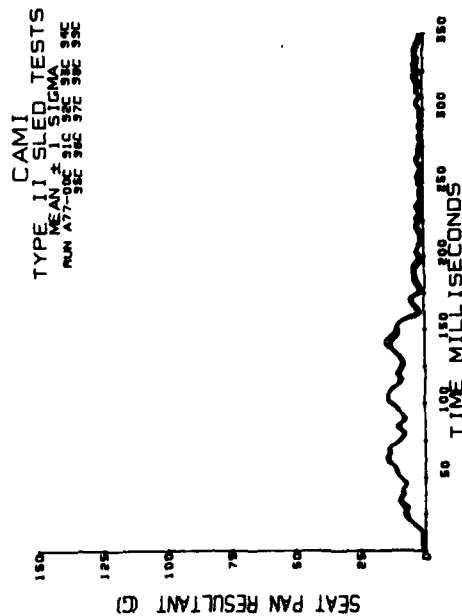
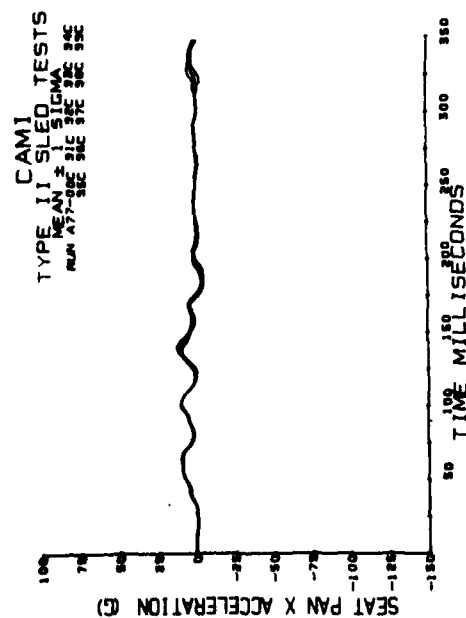
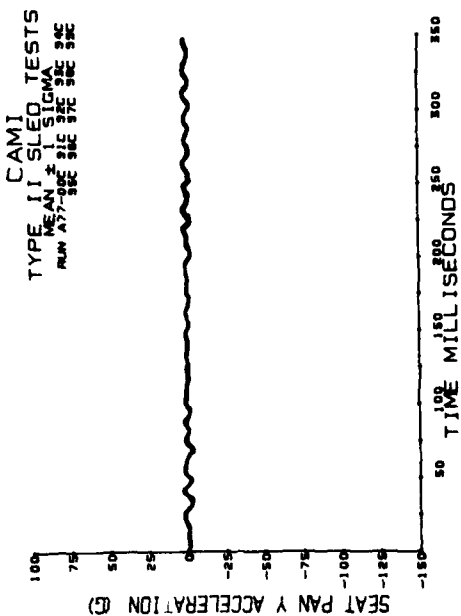


Figure 24. (continued). Seat pan acceleration.

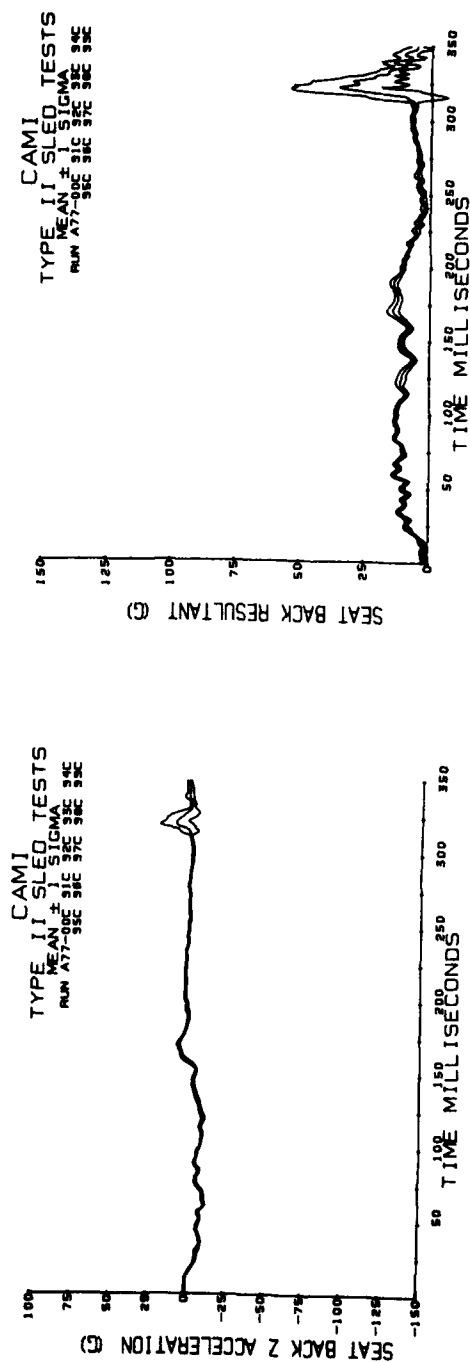
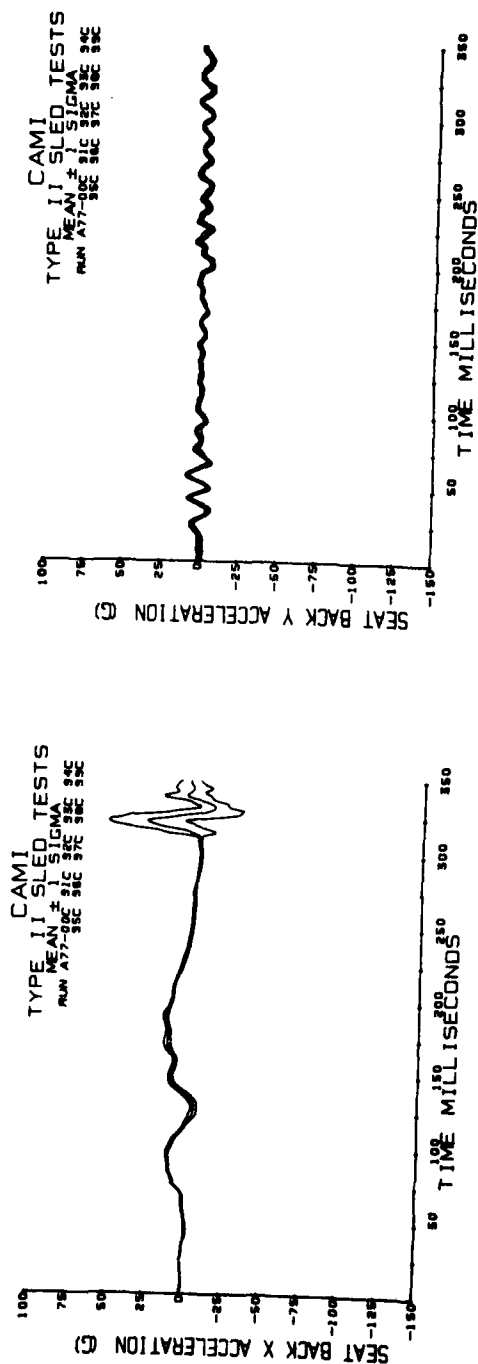


Figure 24. (continued). Seat back acceleration.

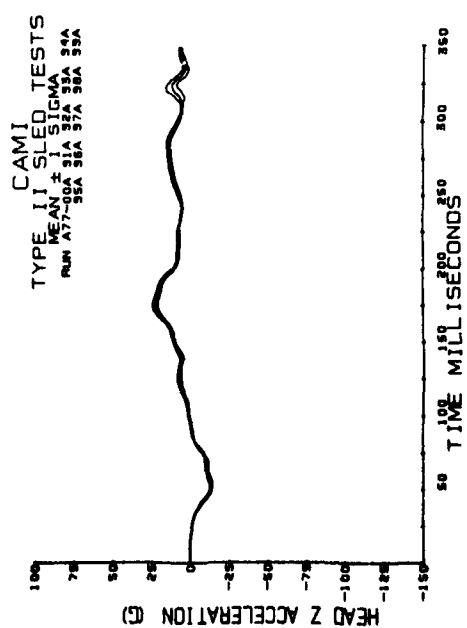
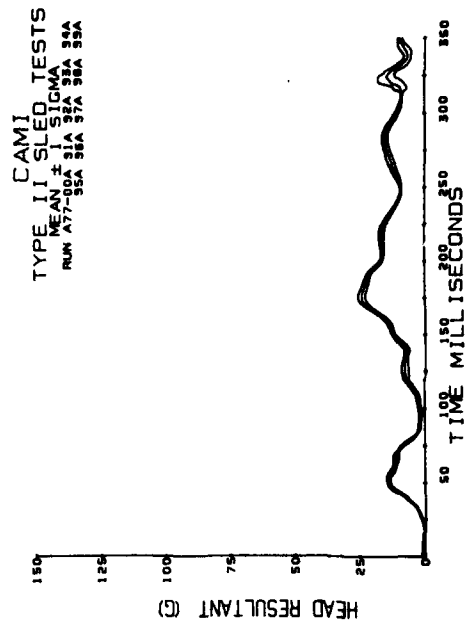
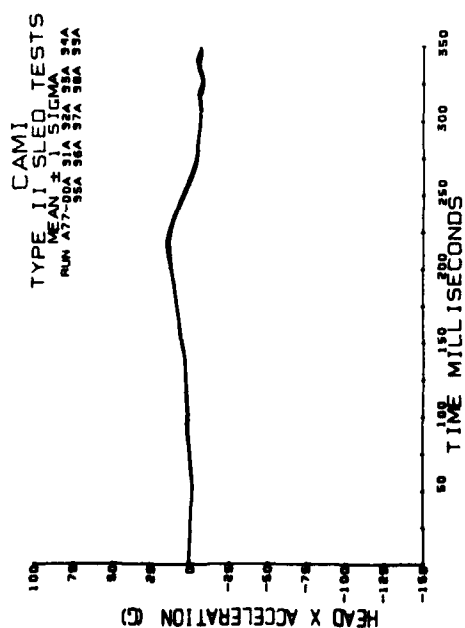
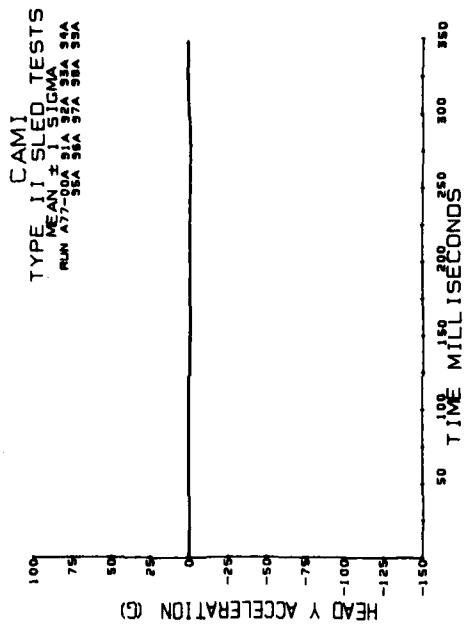


Figure 24. (continued). Head acceleration.

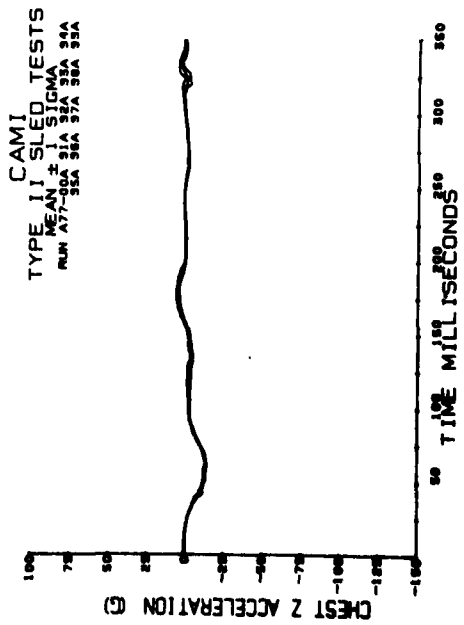
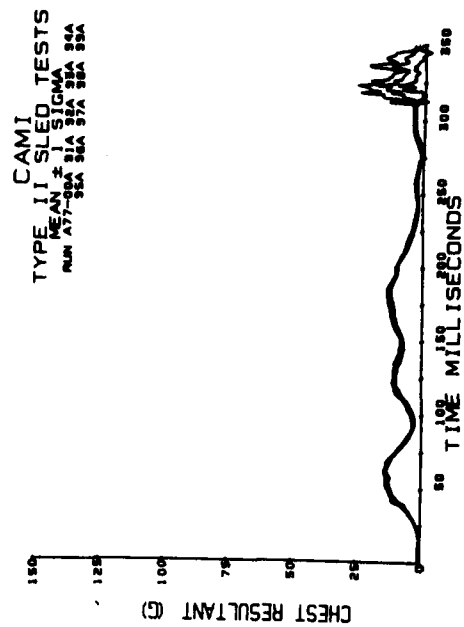
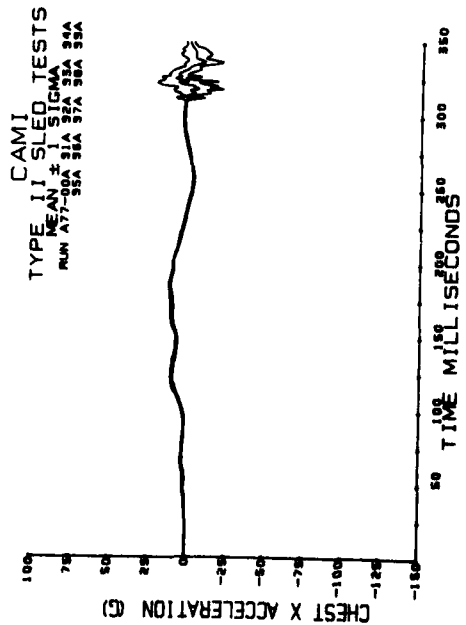
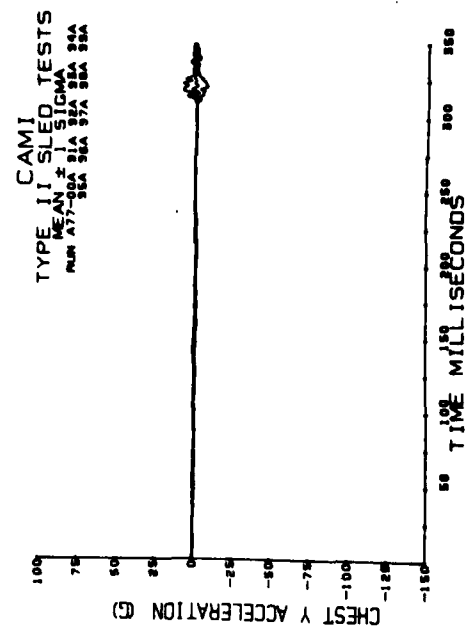


Figure 24. (continued). Chest acceleration.

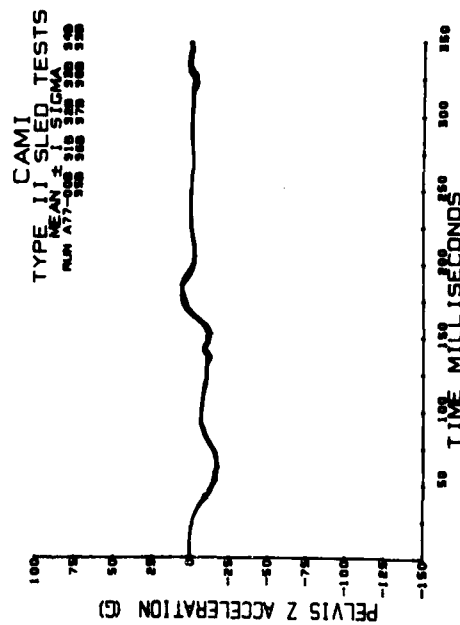
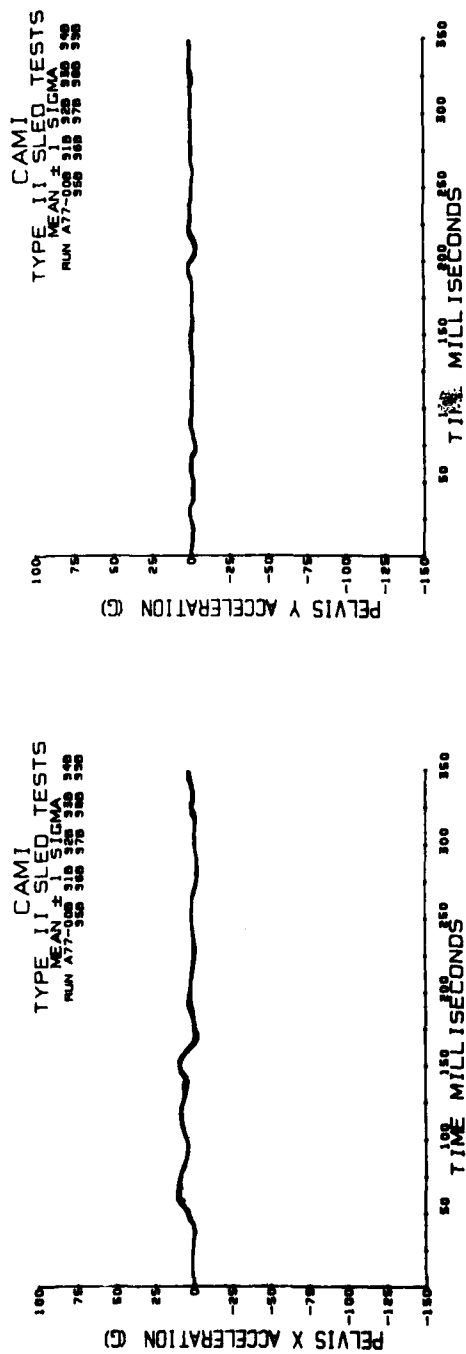


Figure 24. (continued). Pelvis acceleration.

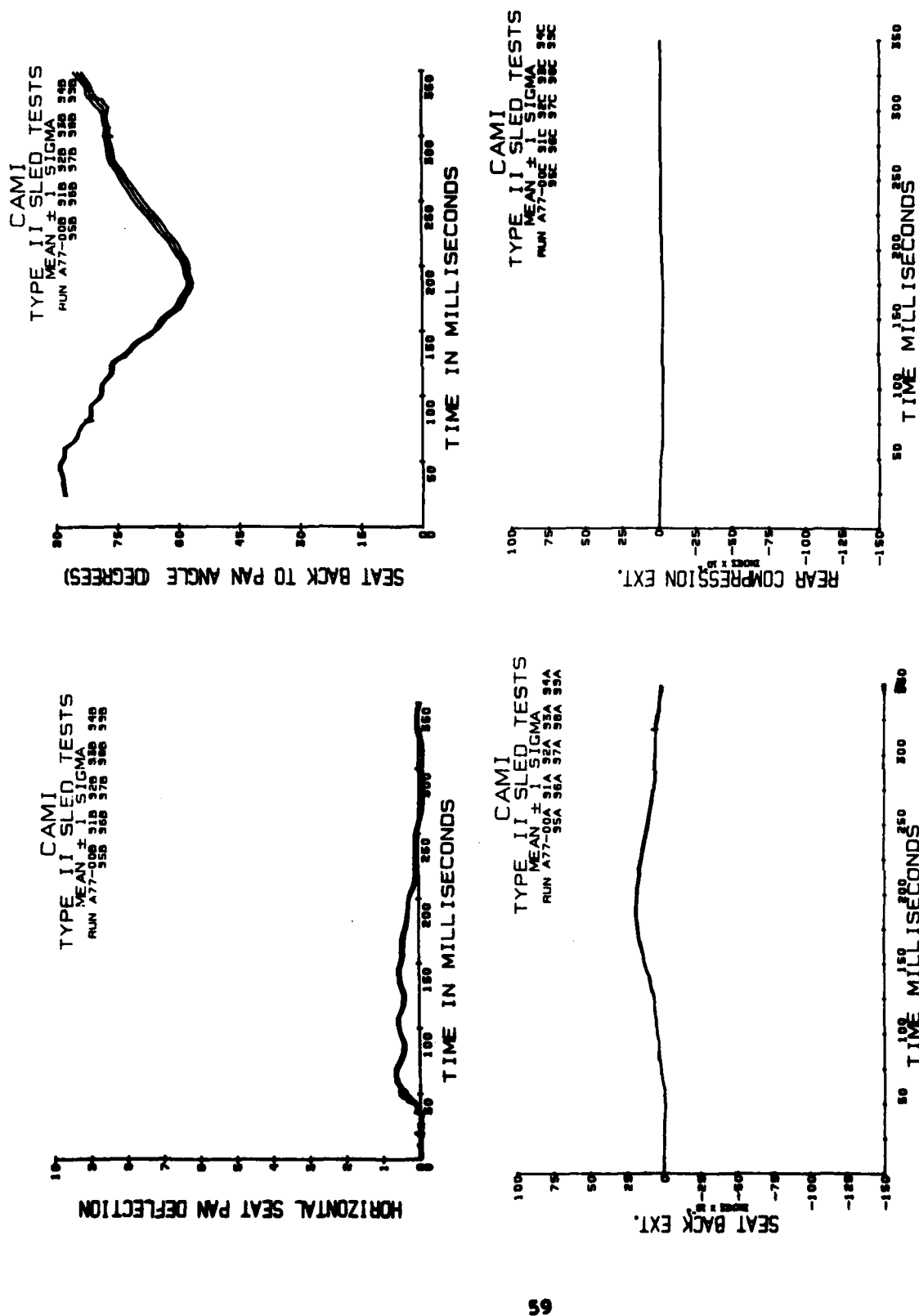


Figure 24. (continued). Seat extensometer data.

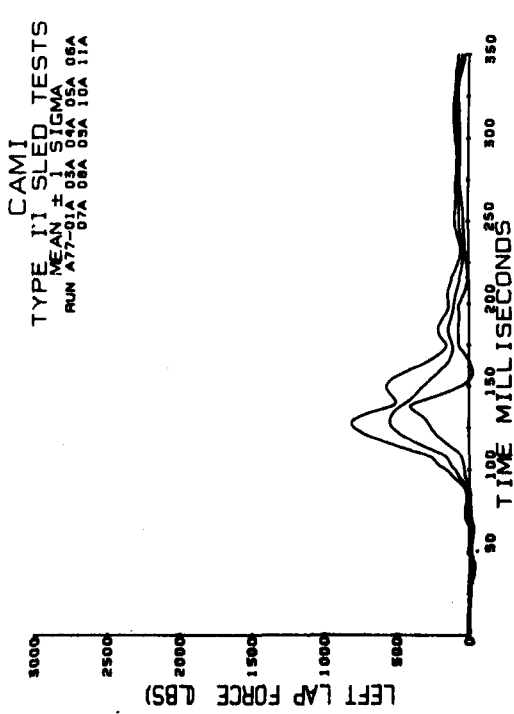
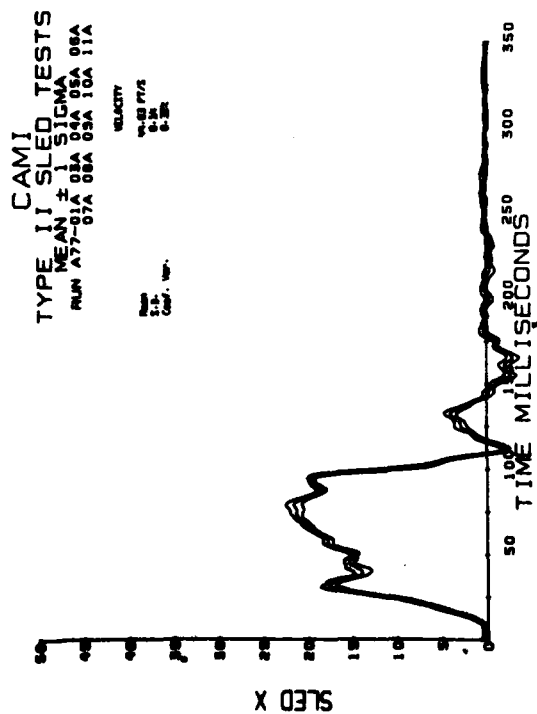
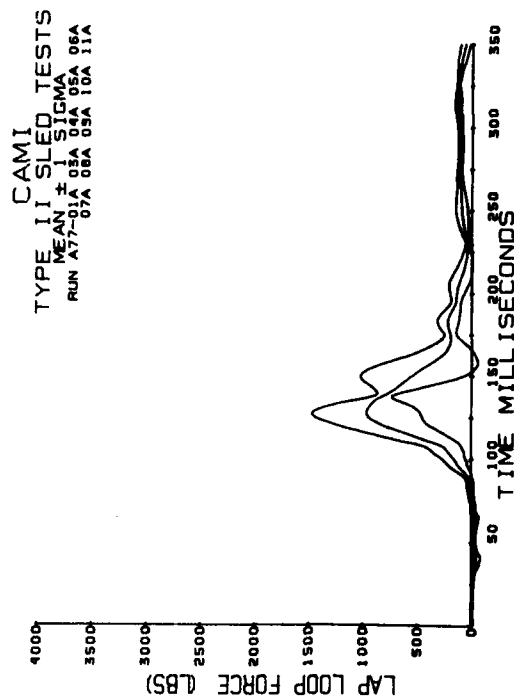
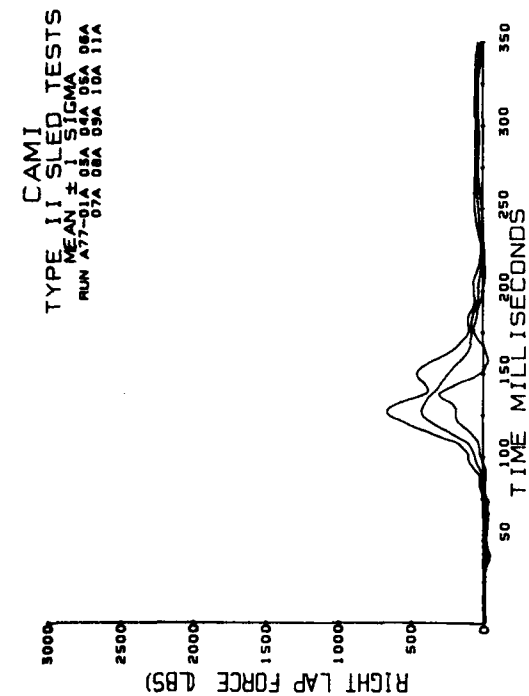


Figure 25. Sled deceleration and lapbelt loads.

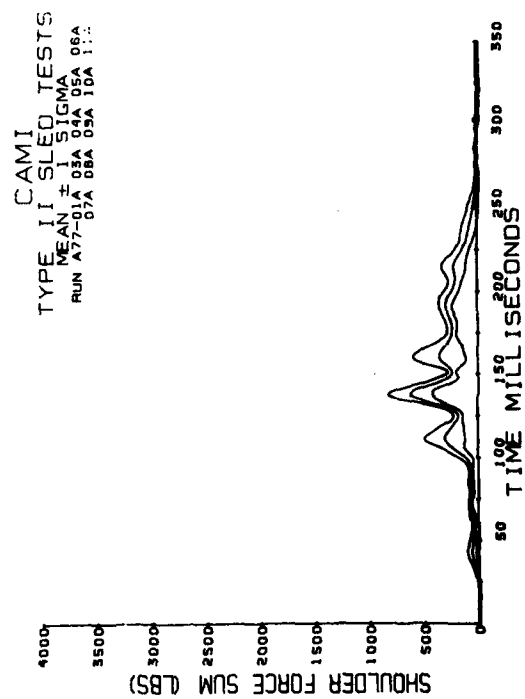
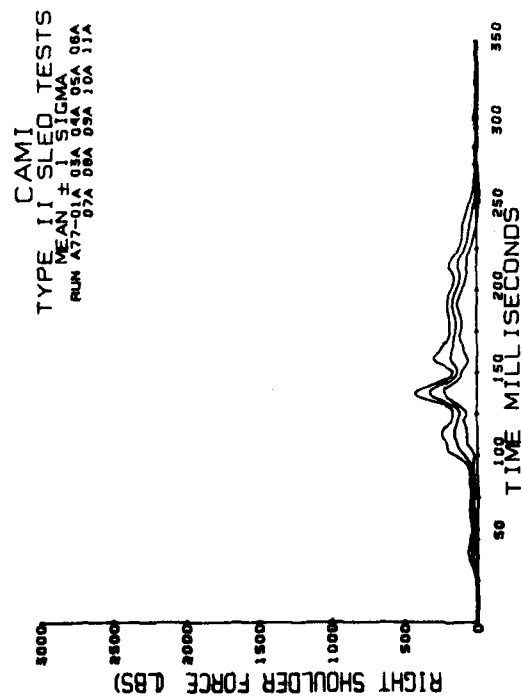
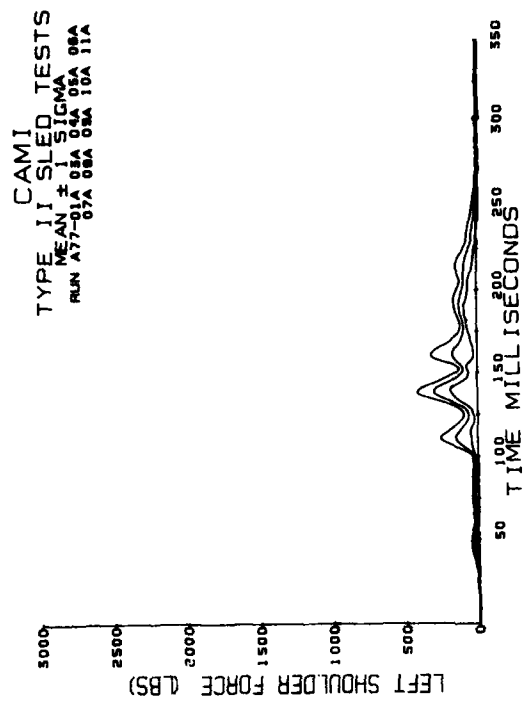


Figure 25. (continued). Shoulder belt loads.

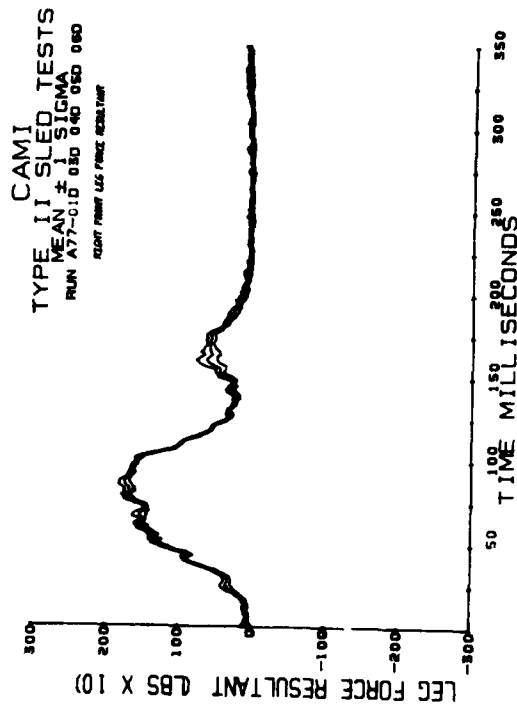
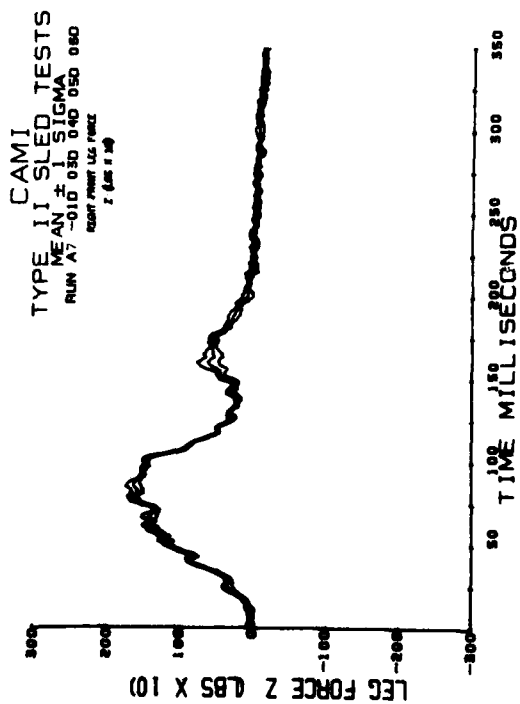
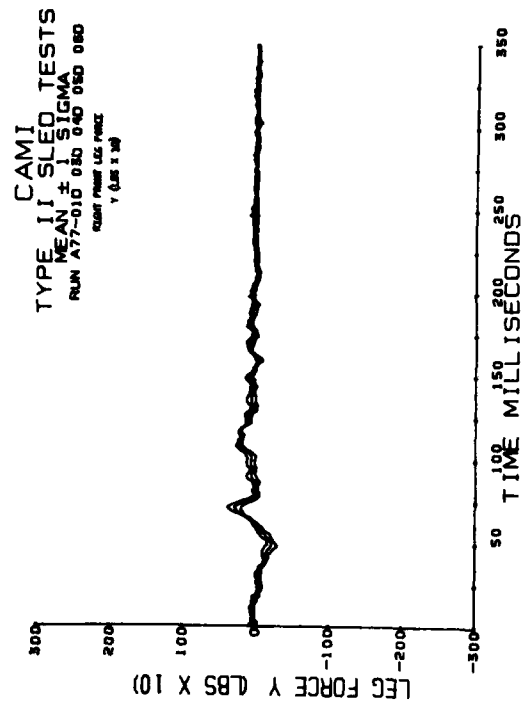
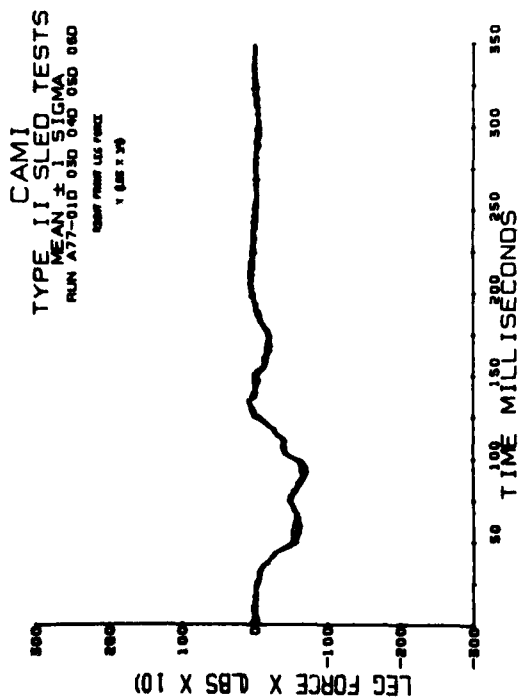


Figure 25. (continued). Right front seat leg loads.

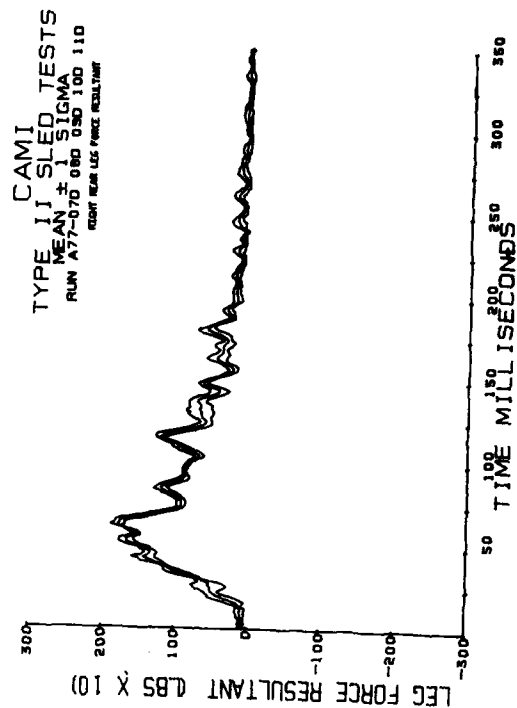
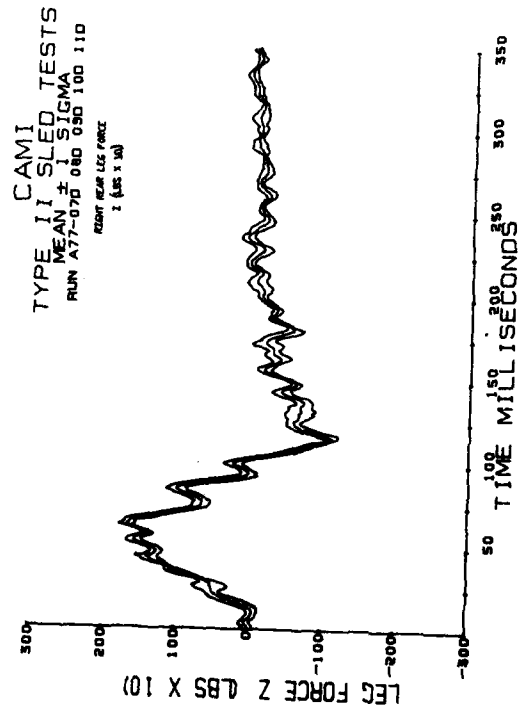
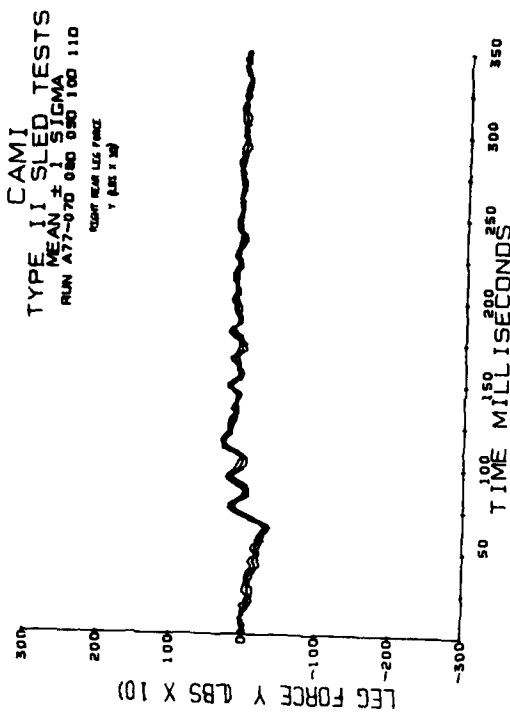
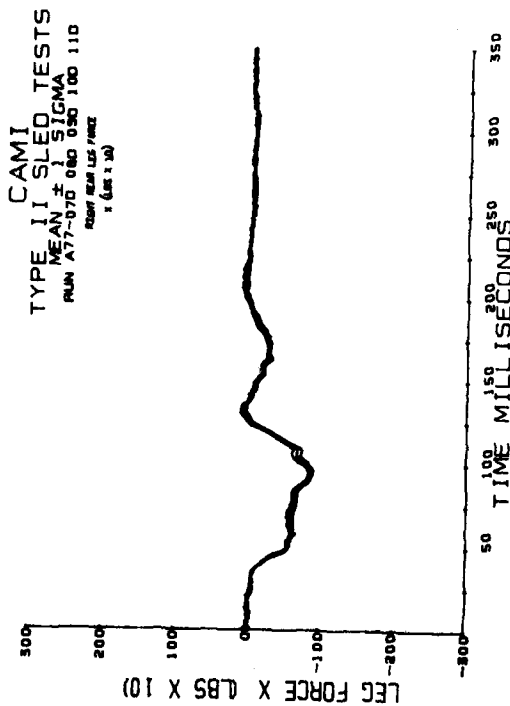


Figure 25. (continued). Right rear seat leg loads.

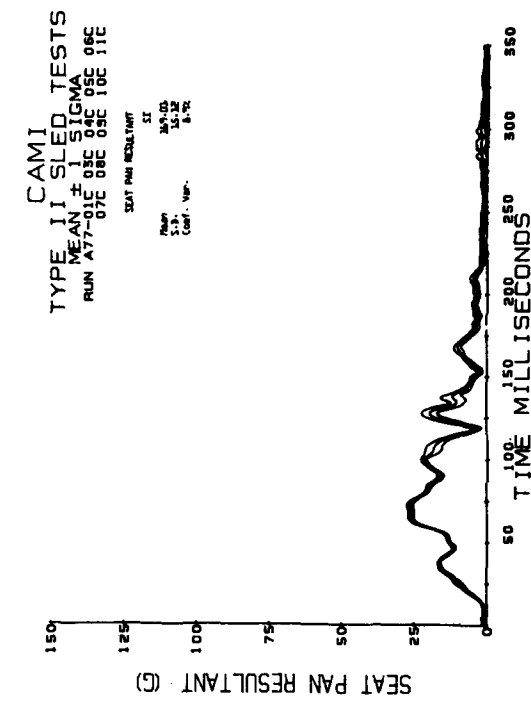
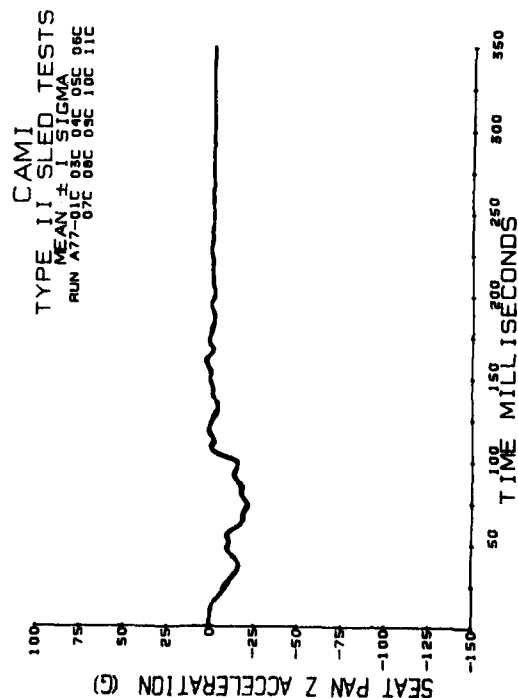
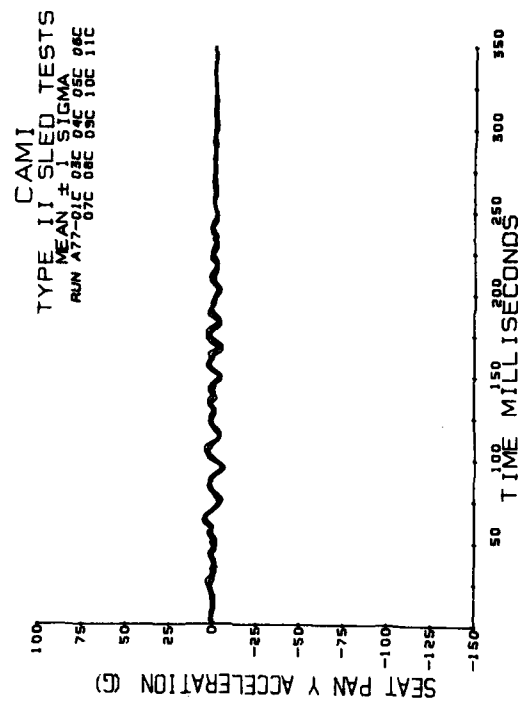
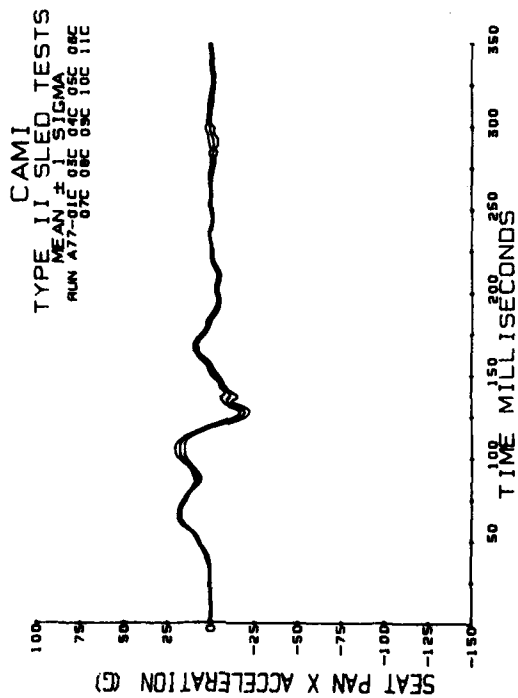


Figure 25. (continued). Seat pan acceleration.

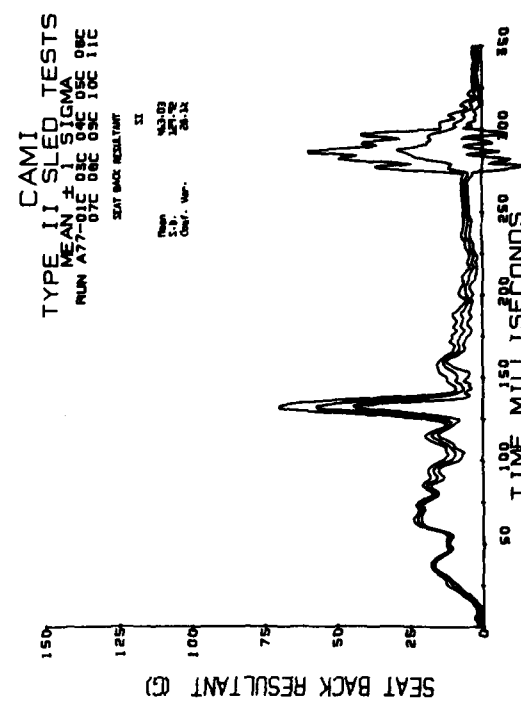
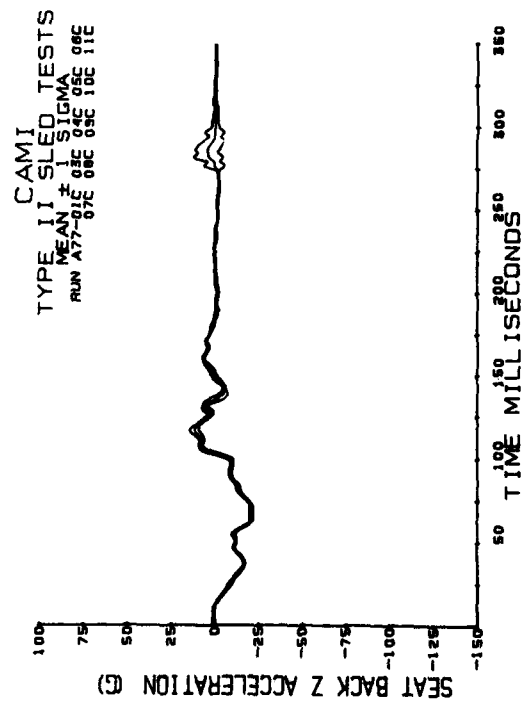
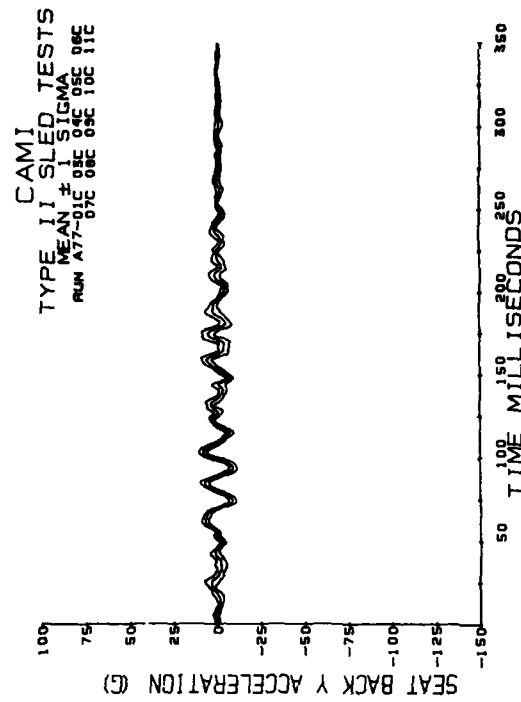
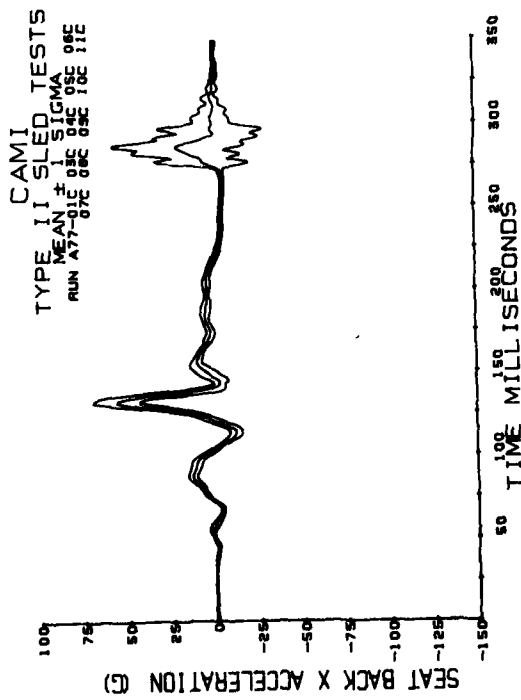


Figure 25. (continued). Seat back acceleration.

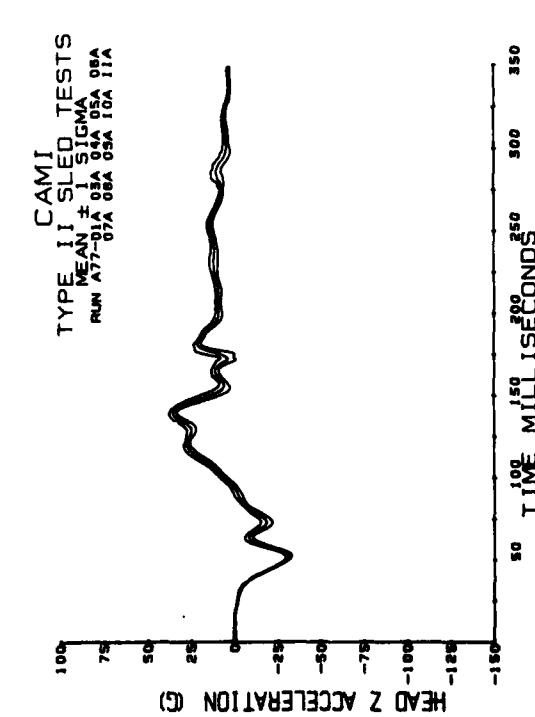
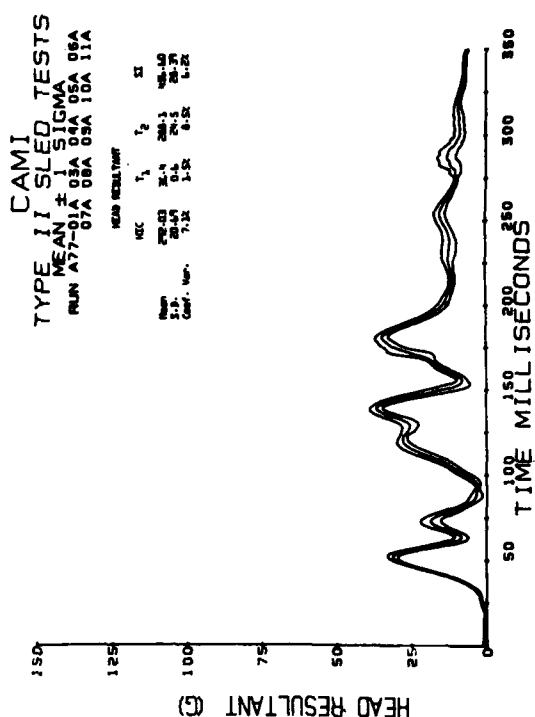
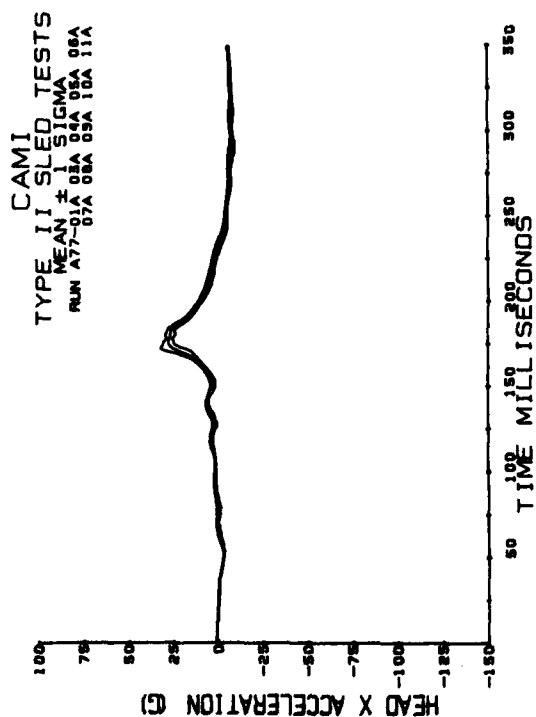
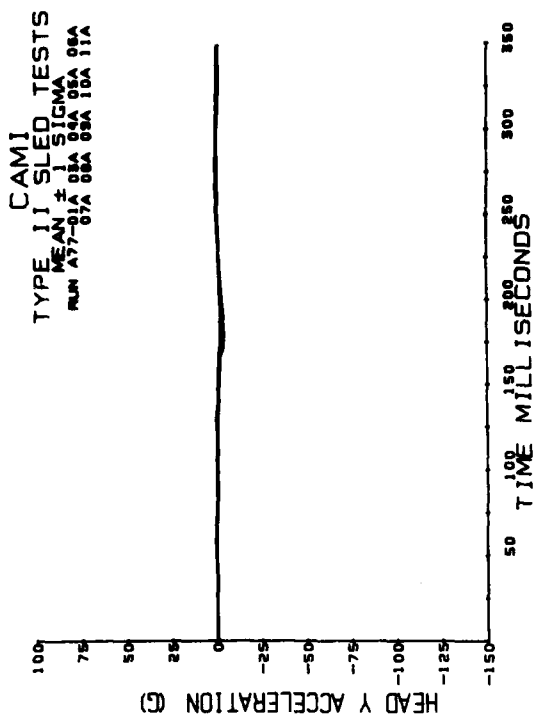


Figure 25. (continued). Head acceleration.

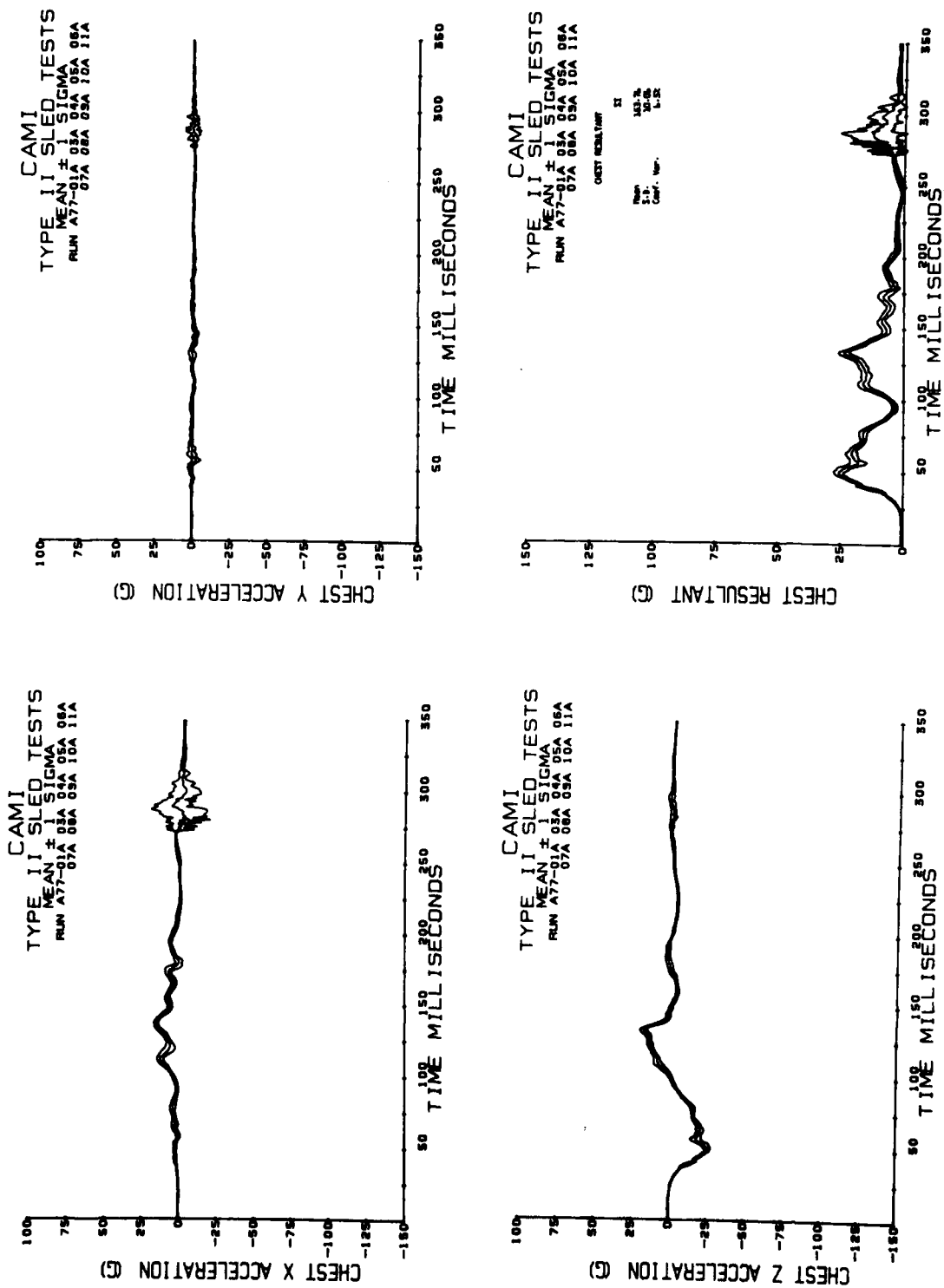
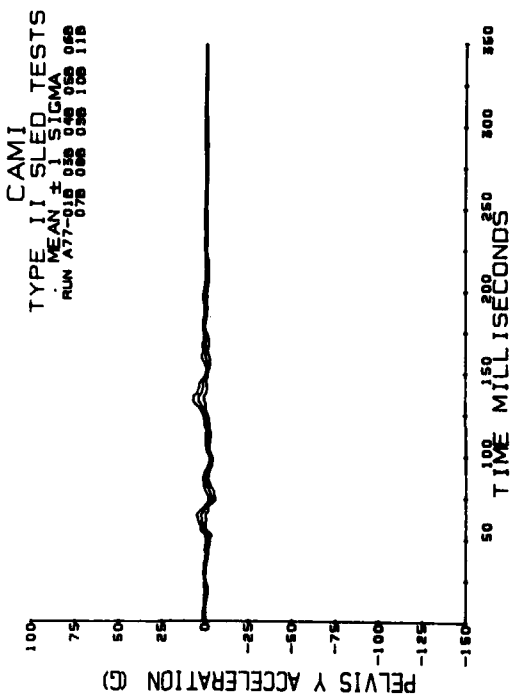
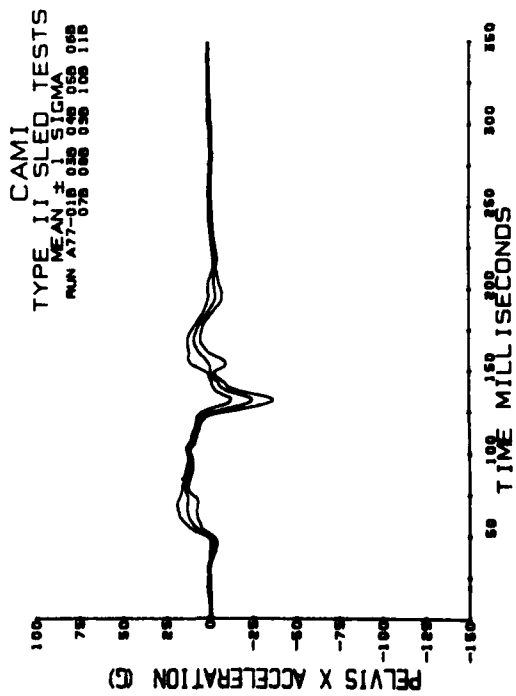


Figure 25. (continued). Chest acceleration.



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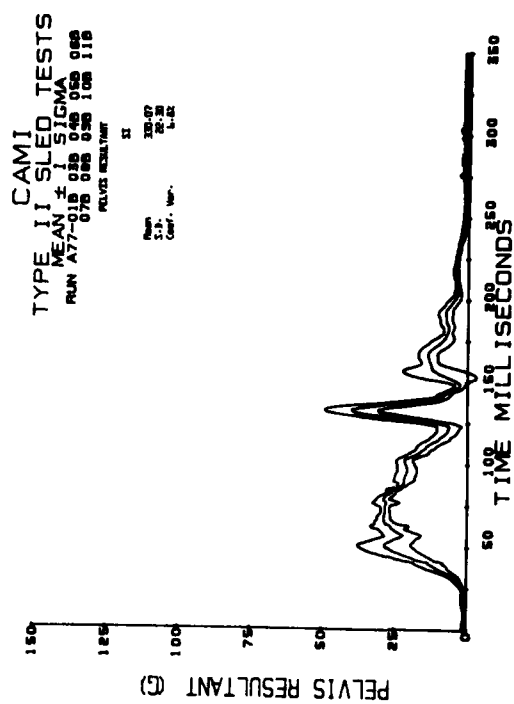
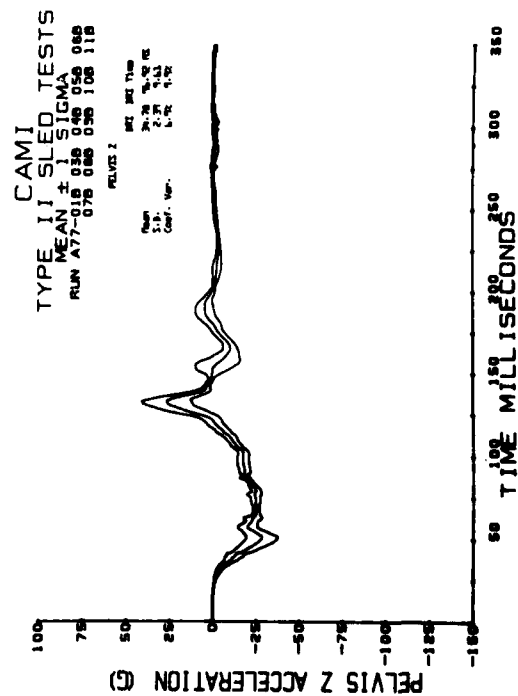


Figure 25. (continued). Pelvis acceleration.

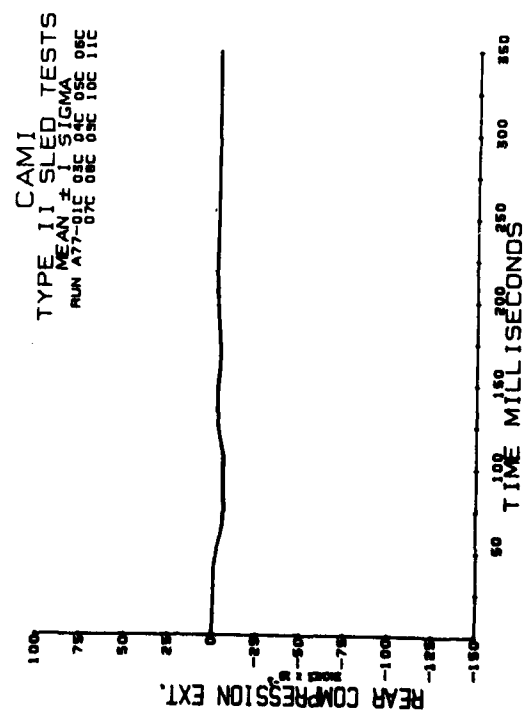
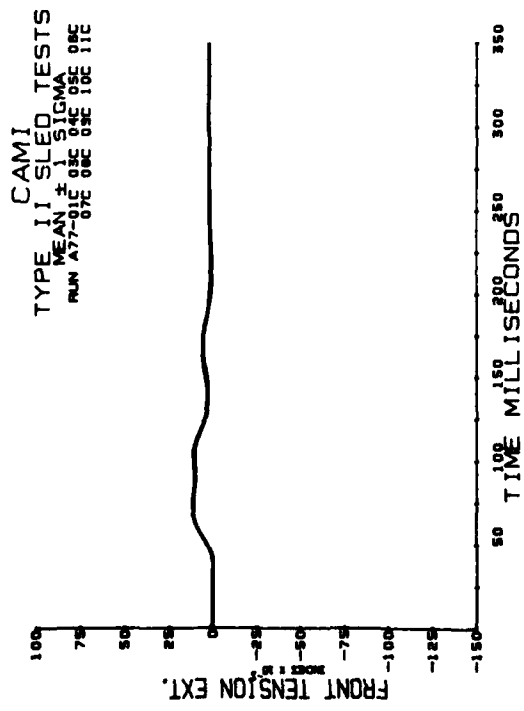
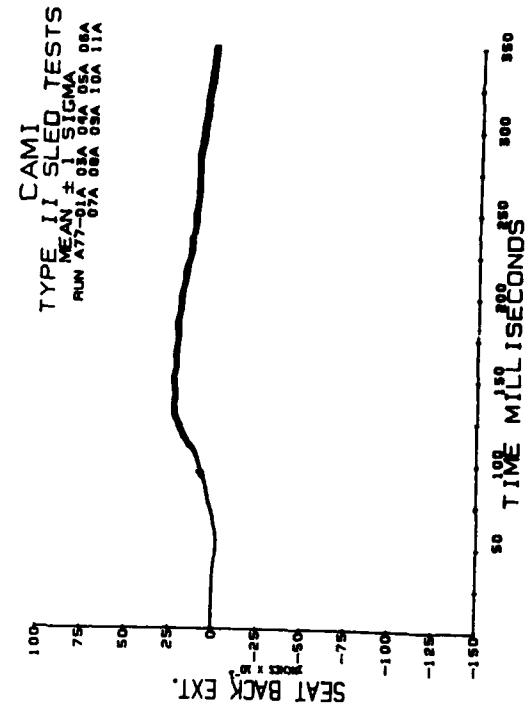
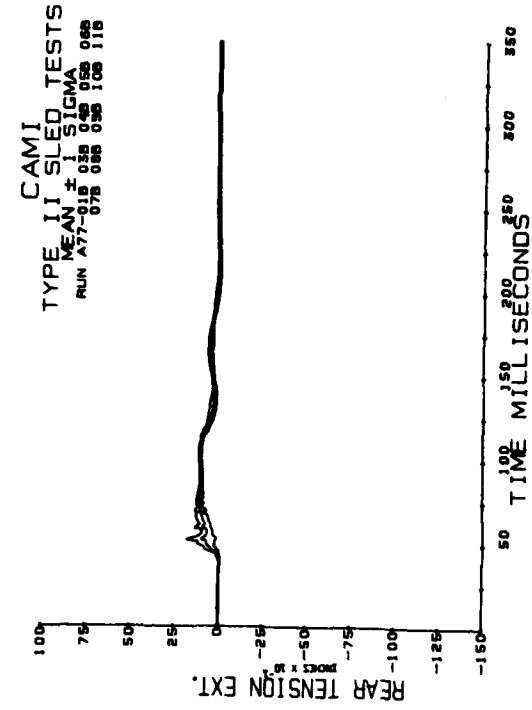


Figure 25. (continued) Seat extensometer data.

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4. Part 572--Anthropomorphic Test Dummy, Notice 1, Docket 73-8.
5. Part 572--Anthropomorphic Test Dummy, Notice 2, Docket 73-8.

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